DIGEST OF INDUSTRIAL AND TECHNICAL DEVELOPMENTS

Travails of Atomic Energy

WITHOUT a detailed study of all earlier atomic energy publications it is hard to know how much of Sir Christopher Hinton's fascinating Melchett lecture was information newly disclosed. This plain unvarnished tale unfolding has a gripping quality. In 1945 Sir Christopher was placed in charge of the production side of the Atomic Energy Organisation without staff, office accommodation or information. Since then, atomic energy has not only grown in scale and significance; it has also changed in emphasis. Up to 1951, the official objectives were still confined to producing material for military purposes. Now a proportion is devoted to civil power projects. This lecture to the Institute of Fuel gains much in dramatic interest by the references to "those problems and difficulties which have been experienced since 1946 and which are not normally mentioned in lectures or articles". For example, one of the major problems in setting to work the chemical separation plant at Windscale was a chemical one. It had always been realized that there would be a small carryover of solvent with the aqueous phase from the first solvent separation column. This aqueous phase consisted of a concentrated solution of nitric acid containing the fission products. The danger that violent nitration of the solvent which had been carried over might take place in the highly active liquor storage tanks and cause dispersion of fission products had been carefully considered. Experimental work had led to the conclusion that such violent nitration could not occur because the small quantity of solvent which was carried over would be steadily and gently nitrated in the acid and therefore an accumulation of solvent capable of giving a violent reaction could not be formed. This experimental work was only proved to be incorrect when the plant was complete and undergoing its final testing with inactive solutions. Of all the major unexpected difficulties that we faced in the early years of the atomic energy industry, Sir Christopher believes that this one threatened our programme most. It was solved by the discovery that if the aqueous effluent from the first extraction stage was evaporated down to a quarter of its initial volume as it left the column, the small quantity of solvent which was carried over was gently destroyed.

Heat Transfer, Sodium to Lithium to Air

"NEITHER the United States, nor the Commission . . . makes any warranty or representation, express or implied, with respect to the accuracy, completeness or usefulness of the information contained in" the published reports of the work they sponsor. This stern standard disclaimer on the cover is not really likely to deter workers from consulting a report by A. R. Crocker *et al* on design and operation of a 50 gallon per minute liquid metal circulating system transferring heat from sodium to lithium to air. The report, No. APEX 327, includes a detailed list of the test equipment with its capital cost and the cost of installation.

Sodium was supplied to the heat exchangers at 1400°F; the average temperature drop was about 400°F. In all six liquid-to-liquid heat exchangers were employed each having one shell and one tube pass, with the shell side fluid baffled to cross the tube four times. The tube side fluid was sodium. For values of about 10,000 for the tube side Reynolds number, the tube side heat transfer coefficient was about 15,000 Btu/hour sq. ft°F and the overall coefficient about 2,000 Btu/hour sq. ft°F. A tinned tube cooler used to remove heat from the lithium gave an overall conductance in the same units of about 5 to 7. Mr. Crocker reports that three years of liquid metal experience have demonstrated that they can be handled safely even though the experience involved several leaks and fires; these were controlled without undue hazard to personnel. The most significant observation was considered to be the absolute necessity for the greatest attainable degree of system purity. This applied not only to maximum initial cleanliness of all wetted parts but also the subsequent exclusion of all contaminants. An all-welded system was unreservedly recommended. Bellows-sealed valves proved to be very reliable once bonnet flanges were seal welded, and the stem and seat alignment were improved by more rigid adherence to specified tolerances on the part of the manufacturer.

Rising Output of Chemicals in Canada

DESPITE some slackening in the pace of business activity in 1957, the value and volume of output of chemicals and allied products in Canada rose by approximately 5% over the level of the previous year, matching the increase which occurred between 1955 and 1956. Chemical manufacturers continued to add to capacity during 1957, and total new fixed investment in the industry is estimated to have been only slightly below the previous peak of $141 million established in 1952. Chemicals which were manufactured for the commercial market in Canada for the first time during 1957 included titanium dioxide, xanthates, synthetic silica-alumina cracking catalysts and hydrogen fluoride. In addition, new or expanded capacity has been completed or is currently under construction for a wide variety of established products. Much of the industry's expansion in 1956 resulted in enlarged capacity for industrial inorganic chemicals, whereas current developments are based more on expanding existing organic petrochemical capacity. Commenting on these facts, H. Greville Smith (*Chemistry in Canada*, 1958, **10**, No. 1, p. 25) observes that despite rising sales, new products and improved technology, the chemical industry is not without its difficulties. Owing to rising costs, in conjunction with extremely competitive market conditions due partly to low tariffs, final figures may show that profits in the chemical industry during 1957 fell below those of the previous year. To follow this article, the journal gives

an impressive list of Canadian industrial projects in the chemical industry and allied fields, then adds for good measure further lists of relevant government and university projects.

Chemical Engineering at Sheffield

THE present Department of Fuel Technology and Chemical Engineering at Sheffield University was originally devoted to applied chemistry. In 1918 it became a Department of Fuel Technology under Professor Wheeler. A considerable amount of chemical engineering teaching was later introduced particularly under Professor Sarjant, and about three years ago at the request of Professor M. W. Thring the title was changed to include chemical engineering. At the moment there are about 35 Ph.D. students doing research mainly on the physics of flames, heat transfer, soot formation, luminous radiation, flow aerodynamics of furnaces and industrial combustion systems by means of models, and also on coal carbonisation. Professor Thring informs us that it is hoped to keep the research strength of the school at about this level or even slightly higher when the new building for the Department is constructed; this is promised for 1960. The building has been planned to contain three 30 ft high laboratories with a central 10 ft basement so that apparatus up to 40 ft high, such as tall columns, can be erected. In general the largest facilities will be used for pilot plant research rather than for teaching, since teaching is best carried out with rather smaller apparatus made as transparent as possible so that the students can see the processes. In the coming session there are due to be 18 undergraduates. During the next decade, when the "bulge" comes through, the numbers should rise to about 40 a year. Students of the department are eligible to join the Institute of Fuel or the Institution of Chemical Engineers. In the latter case they have to take the home study paper afterwards. There is not time in the course for this work, since students prepare an experimental thesis in their third year.

Throttling Flow Meter with Low Head Loss

UNDER this heading in our February issue we referred to the double throat tube of Bopp and Reuther G.m b.H. and commented on its apparent similarity—in form and results—to the Dall tube of George Kent Ltd. Now Mr. H. E. Dall has kindly tabulated for us a summary of the published information* on these devices.

Nozzle Venturi B. & R. Short Pattern		Equivalent B. & R. Double Throat Tube	Equivalent Dall Tube
$m=\left(\frac{d}{D}\right)^2$	Loss Fraction, % of Diff. Head	Loss Fraction, % of Diff. Head	Loss Fraction, % of Diff. Head
0.10	21.5	12.4	7.3
0.20	17.5	8.1	6.1
0.30	14.3	7.0	4.4
0.40	11.8	6.4	2.8
0.45	10.7	6.2	2.4

The first two columns refer to the old device, namely the short pattern Nozzle Venturi, and the last two columns to the newer devices designed to give the same differential head at the same flow. The discharge co efficients of these newer devices differ considerably from that of the Nozzle Venturi, hence the throat sizes for "equivalent" duty are not the same. The overall length of all three devices is substantially the same; some variations may be found but these depend mainly on the length of parallel approach provided in the unit. Without any reflection, however, on any of the investigators involved it would still be interesting to see what a third party had to say about the properties of these interesting instruments.

* *V.D.I.*, Bd 96 (1954) No. 11/12, p. 347. *Trans. A.S.M.E.*, 1956, 78, No. 3, p. 475.

Corrosion in Tubular Condensers at Power Stations

IN great detail, A. J. Maurin has published a series of studies* giving some characteristic examples of corrosion phenomena in French power stations. A range of alloys were tested exposed to a variety of water compositions and boiler operating conditions. Many types of scientific armament were brought to bear in a group of chemical, electro-chemical and metallographical investigations which also took costs into account. The resulting generalisations are largely extensions of current lines of thought. Protective procedures should aim at polarisation of a metal by inhibition or cathodic protection. Alternatively they may be directed to preventing depolarisation. The causes of corrosion are those factors tending to cause depolarisation. Mechanical causes listed by Ing. Dr. Maurin are erosion, abrasion, turbulence or vibrations. Troublesome Redox-type phenomena include reduction by bacteria or by H_2S caught up in deposits. Differential aeration, differential copper ion concentration, pairs of different metals or different oxides are all capable of setting up troublesome primary cells. Finally stray electric currents are occasionally the culprits. But it is evident that the author—founder of the French Association of Anti-corrosion Engineers—considers personal experience more valuable by far than these generalisations. For in his conclusion he quotes approvingly, from an O.E.E.C. pamphlet on combating corrosion in U.S.A., the following *desiderata* for the corrosion engineer. "He must be able to listen to all grades of workers and to prove that he is not afraid to dirty his hands". These papers show that Dr. Maurin has very usefully acted on his own advice.

* *Corrosion et Anti-corrosion*, 1957, 5, pp. 275 and 383; 1958, 6, p. 15.

Prevention is Better than Froth

BETWEEN 1949 and 1954 the total U.K. consumption of surface active material rose from 13,000 to 39,000 tons per year. Since then there has been a much slower rate of advance and the 1956 figure was only 41,000 tons. The Standing Technical Committee on Synthetic Detergents in their latest progress report comment that they consider further expansion of domestic or industrial consumption unlikely. Apparently, foam on rivers, canals and sewage works provokes most of the complaints to this Committee. But there is a reciprocal problem. Many people are worried about the possible effect on conditions in rivers of the anti-foaming agents in use at sewage works. The earlier Jephcott Committee recommended that manufacturers of household synthetic detergents should investigate the feasibility of producing efficient washing products based on materials which can be readily oxidised or eliminated and will not cause persistent foaming during sewage treatment by present available methods. For treating foam, there are two remedies at present in use at sewage works. One is to add chemical anti-foaming agents and the other is to break down the foam mechanically by spraying with water. It has also been found that if the activated sludge process is so operated as to effect a substantial measure of nitrification, foaming in the aeration tanks does not reach objectionable proportions. All these

remedies however are only unsatisfactory palliatives. The Metropolitan Water Board have offered to test on a laboratory scale the biological decomposability of any compound which a manufacturer is proposing to market. A similar offer has been made by the Water Pollution Research Laboratory for pilot scale tests for the same purpose.

Push Button Dangers and Others

CHEMICAL industry receives special—and favourable —mention in the current (1956) Annual Report of the Chief Inspector of Factories. The reduction to 1.35 in the number of lost time accidents per 100,000 man hours worked is considered "particularly interesting" because it was achieved in a year of increasing production. Other trends of the times are also discussed. The tendency to use individual drives on machines in place of belts and shafting may result in accidents due to inadvertently starting up machines. A definite physical effort is needed to shift a driving belt but push buttons need only light finger pressure. Manufacturers of starters are criticised for not always giving enough attention to shrouding the start-buttons. Studies of reliability of complex electrical and electronic gear—mentioned in the same report—are of increasing importance in chemical production for evident reasons. Circuits should be as simple as practicable and components under-stressed or under-run in normal use. A noteworthy curve is presented showing the rapid fall in reliability of equipment as the number of components increases. This gives a useful background for appraising the control systems offered by enthusiastic young electronic engineers. Like much safety advice, a proportion of the comments by the inspectorate seem quite banal, such as "extreme care must be taken . . ." Yet equipment does often fail due to neglect of the obvious and it must be confessed that urging people to take care seems a sensible component of safety precautions.

Operational Research on Safety

IN the new magazine "Safety" published by the British Iron and Steel Federation, most of the material is naturally devoted to the problems of the federated industries. But the article by S. Laner on investigating human factors in accidents has much wider application. Discovery of a striking set of statistical relationships—though this suspect adjective is not mentioned—leads to an important conclusion. Effective accident prevention is by no means a matter purely of providing mechanical protection of the machine or worker, nor of exhortation and propaganda. Selection, placement, induction and training have all been shown to be part and parcel of the effort to eliminate accidents. What is the evidence? The investigators' hunch was that light might be cast on the nature and significance of accidents by relating them to other events in a worker's industrial life and regarding them as aspects of the social "climate" within the works. For example, comparisons were made between those who stayed with the company more than four years and those who left. With length of exposure taken into account it was found that the leavers had about half as many accidents again as the stayers. As a further instance the relationship between the accident record and the "no reason" absence record was tested for the 289 stayers. It was found that of the 150 individuals who had any "no reason" absences in the first six months of their service, 38 per cent sustained accidents. Of the 139 who had no unexplained absences during that period only 23 per cent sustained accidents. This suggests the possibility of predicting which of the new entrants is likely to suffer accidents by studying his "no reason" absence record during his first six months with the firm. Here is a final example. Dr. Laner shows a graph of the lost-time accidents sustained by the 289 stayers during the eight consecutive half-yearly periods from the day each of them joined the company. The general trend indicates that the number of accidents sustained has been almost halved by the end of the fourth year. Much the same is true of the number of days lost through accidents. The study contains no false claims about *causal* relationships and one might reasonably speculate that a common cause is involved; an unstable temperament might lead to rapid leaving, resistance to learning and liability to accidents. For further clues we shall evidently need more research and we would suggest only one further thought, and complication. to the operational researchers. It is a step forward to look at accidents, not solely in terms of themselves, but as part of each worker's industrial life. But many other social factors will also be exerting an influence.

Calculating Flow in Hydrocyclones and Centrifuges

A NEW contribution to the study of flow conditions in hydrocyclones and centrifuges has been made by H. Trawinski.* The flow processes for suspensions in centrifuges and more important in hydrocyclones have not previously been calculable. Dr. Trawinski points out that it will be impossible to calculate the conditions in any device producing three dimensional vortices, including equipment used for dusts, until unambiguous conditions can be created within it by means of forced flow, as has been possible in the case of the spiral air elutriator. The investigation reported therefore covers the derivation of formulæ which can be used for calculating the most important data for the hydrocyclone and centrifuge. The throughput, peripheral velocity, radial acceleration and residence time are discussed separately. In addition model laws are derived for calculating the cut point. Vortex stability in the cyclone and equilibrium orbits in the cyclone and centrifuge have been investigated by the known relationships in the spiral air elutriator. In order to link knowledge about hydrocyclones and aero-cyclones the author has also developed a model theory for conversion of the operating data. From model considerations he concludes that it is uneconomic to attempt to develop large apparatus with high throughputs for cut points of fine size.

* *Chemie-Ingenieur-Technik*, 1958, **30**, p. 85.

Control Engineering at Cambridge

AT Cambridge University newly-completed extensions to the Engineering Laboratories will add 14,800 square feet of floor area while a further wing providing an additional 28,700 square feet is under construction. In the description kindly sent to us by Professor Baker it is stated that part of the extension is planned to house a Control Engineering Group. In this section the teaching laboratory is equipped for a number of class experiments to illustrate the principles of automatic control and simple electronics. Provision has been made for individual experiments on such topics as magnetic amplifiers, digital computing techniques, pneumatic controllers and rotary amplifiers. Some analogue computing equipment is also provided for the simulation of simple control projects of their own choice. A separate research laboratory provides accommodation for six research students, including provi-

sion for hydraulics research. Equipment has been built for work on control systems with predicted time of change-over to give the best performance for varying loads as well as changing input and for recording and analysing random processes. Apparatus for the investigation of the design of non-linear filters to discriminate between random processes having the same spectral density will shortly be moved into this laboratory from its temporary quarters. A computing room will house analogue computing equipment required in the simulation of non-linear filters and control systems. Some of the equipment is being set up as a small analogue computer for the solution of non-linear differential equations and the investigation of well defined problems. The remainder will be used as required in simulators set up in the course of researches of the type described above.

Towards Cleaner Air

FIRST of June, 1958, is the date of operation of all those provisions of the Clean Air Act, 1956, which are not already in force. They include sections prohibiting the emission of dark smoke from chimneys, regulating the discharge of grit and dust from furnaces, providing new powers for dealing with smoke nuisances and prohibiting dark smoke from railway engines and ships. The Minister of Housing and Local Government is due shortly to make regulations in connection with this Act and also an order to extend the list of works and gases controlled under the Alkali Act of 1906. Some two years ago the Ministry issued a notice inviting representations on extending the scope of the Alkali Act. In the evidence brought before the subsequent public enquiry it was noteworthy that local authorities favoured keeping industries subject to the Clean Air Act while industrial representatives favoured scheduling processes under the Alkali Act. What are the points at issue? The requirements of the two Acts are much the same in requiring the prevention of air pollution but the Alkali Act appears to allow more tolerance concerning the "best practicable means" of preventing it. Furthermore, under the Clean Air Act the inspection would be carried out by local officers and it would be possible for the local authority to take action against any offender themselves. For the moment the struggle seems to have been resolved and the Minister has now decided that those industrial processes which present special technical difficulties in regard to preventing pollution by smoke, grit or dust require the attention of a single inspectorate with special technical qualifications. They should therefore be scheduled under the Alkali Act. At the same time the Minister recognised the responsibility of the local authorities and accepted that there should be no unjustified diminution in their powers to control air pollution. The extension of the Alkali Act should therefore be strictly limited to those processes which in fact present special difficulties. The works scheduled in this way include lime works, ceramic works, caustic soda works and so-called chemical incineration works.

Organic Vapours Change the Crystal Habit of Ice

IS there any bearing on freeze-drying practice in the results of recent investigations by J. Hallett and Dr. B. J. Mason on the crystal habit of ice? Ice crystals grown from the vapour, both in atmospheric and in laboratory supercooled clouds, show the following remarkable variation of habit with temperature: 0°C to −3°C, thin hexagonal plates; =3°C to −8°C, needles and hollow hexagonal prisms; −8°C to −25°C, plates; stellar dendrites around −15°C; −25°C prisms. In a short paper in *Nature* (Vol. 181, No. 4607, p. 467) Hallett and Mason point out that the presence of traces of organic vapours may profoundly influence the growth habit of ice crystals. For example, crystals grown in a diffusion chamber in which isobutyl alcohol has been added to the water source show remarkable changes of shape as the concentration of alcohol vapour is varied from 0 to 1 mb. partial pressure. The most striking variations of crystal habit with increasing concentrations of alcohol occur between −12°C and −16°C. When the partial pressure of the alcohol exceeds about 10^{-3} mb. the normal dendritic growth is suppressed and replaced by plate-like crystals. A further rather small increase in alcohol concentration causes these to be replaced, either by hollow prisms or by needles, which persist until the concentration is raised beyond 0.1 mb., above which there is a further transition to plates, and finally, at higher concentrations still, a reversion to a rather stunted form of dendritic growth. An earlier observation by Vonnegut, that a cloud of tiny hexagonal plate-like crystals, growing at −20°C, was transformed into hexagonal prisms by the addition of butyl alcohol at a partial pressure of about 10^{-2} mb. was confirmed by these workers. They also found that a reversion to plates occurs if the concentration of butyl alcohol exceeds about 0.2 mb. Similar transitions are also observed in the temperature-range −8°C to −12°C.

High-pressure Gas Plants

THE decision to build two gas making plants in Britain to operate high-pressure processes is a bold step along the road of regarding coal as a raw chemical material rather than merely as a fuel. Both plants—at Partington (see p. 193) and in Fife—will employ either initially or later, a hydrogenation process elaborated at the Gas Council's Research Station at Solihull, and they will use low-grade coals. Both are being installed by Humphreys & Glasgow. The more important plant, so far as production is concerned, is that to be erected by the Scottish Gas Board near open cast coal workings at Westfield, Fife. It will be installed in two stages, the first being the completion by 1960 of a Lurgi plant, with the co-operation of the Power Gas Corporation. The second stage, due for completion two years later, will include the addition of the hydrogenation process, and it should double the output of the installation to 30 million cu. ft. a day. At capacity the plant will consume annually 400,000 tons of open-cast coal, containing 25% ash and 16 % water. The raw product will be transported by conveyor directly from the National Coal Board site to the Lurgi plant, so that freight charges on the coal will not enter into the cost of the gas production. The coal will be completely gasified at a pressure of 25 atmospheres in a stream of oxygen and steam, the ash being returned to the coal workings and the plant effluent discharged to the Firth of Forth without treatment. The calorific value of the Lurgi gas will be enriched from about 400 Btu per cu. ft. to the value required for distribution, with, in the first stage, butane obtained from Grangemouth, and in the second stage, by hydrogen from the hydrogenation process.

Other developments planned by the Scottish Gas Board include the eventual building of an interlinked "national high-pressure gas grid" for Scotland, the distribution of more coke-oven gas from Lanarkshire and the further exploitation of methane from collieries. The Board also propose to convert to smokeless-fuel production gas works that no longer will be required for gas making.

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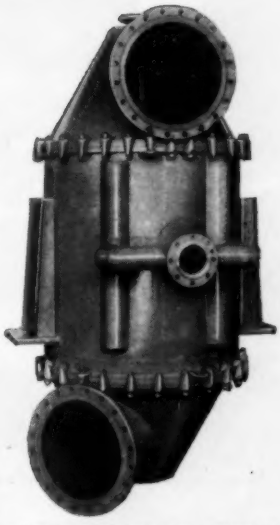

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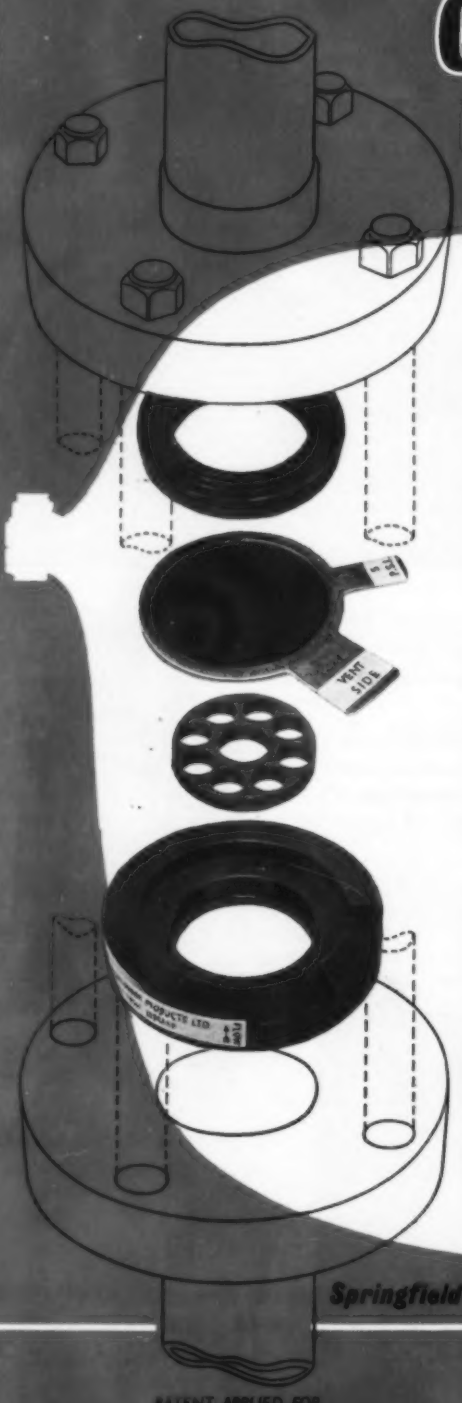

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A HEYWOOD PUBLICATION
British Chemical Engineering

A Useful Study?

WHAT kind of an impact has work study made upon chemical engineering, how useful and durable a tool is it and what is its future? These questions are naturally prompted by the aggressive and apparently excessive publicity which has surrounded the subject. The conferences devoted to its practice, its adoption as an instrument of management by a number of large chemical manufacturers, the fact that it is now an optional subject in the qualifying examination for corporate membership of one of our most august and senior professional engineering institutions, are factors which counsel caution to those who might otherwise dismiss it summarily. Nevertheless, those to whom it is something of a novelty are justified in approaching it with trepidation, for there have been many loudly heralded panaceas in the past which have been with us one day and a day or two later have been forgotten. It cannot be denied that some aspects of work study, particularly the measurement of human effort by time, are not popular with some engineers, partly perhaps through superficial humanitarian objections but mainly because such practices do not call into play the traditional skills of the engineer. And, as with many other allegedly new tools, many of us may suspect that this one is nothing new but something aged, salvaged and reclothed in a new terminology. But however resentful we may be of its kinship to the ideas of Bedaux—ridiculed some two decades ago in an outstanding piece of cinematographic artistry—we should not be short-sighted in our approach to work study nor allow our appreciation of its real achievements to be blunted by emotion. At first sight the fact that of the total cost of many chemical products labour constitutes a very small percentage—in the columns of this journal we quoted recently figures of the order of 3% for large-scale gas separation plants—gives the impression that there is little scope for work study within the chemical industry. This impression is reinforced by the tendency to extend the use of automation, and for larger plants to be built so that the labour content of many products will diminish.

We should recognise in the first place that work study has already proved its value in the light engineering industries, which are characterised by short-cycle, highly repetitive actions. Very significant increases in productivity, and therefore greater returns on investment, have been achieved through it. But the operations in this industry are relatively easy to measure, whereas in the chemical and processing industries they are a great deal more subtle. In many cases there is a far greater degree of responsibility, and frequently there has to be an emphasis on safety. In these industries there are cases where repetitive operations do, in fact, arise; for example, where an end-product has to be filled into large numbers of containers, labelled and packed for dispatch to the selling points: the manufacture of pharmaceuticals, insecticides and detergents are cases in point. Operations of this kind have been very successfully tackled by work study and quite spectacular savings in labour have been achieved.

With process work, especially when it is desired not only to rationalise human effort but to evolve a system of payment by results, the application of work study is far from simple. For one thing, manual efforts only can be measured, and the efforts of reading instruments and making deductions from them prior to making adjustments in the process are impossible to measure directly. Of course, it may be argued that a direct measure of the mental effort is the output of the plant and this conception has been used successfully in a number of incentive schemes, but this is scarcely work study. Easily-controlled processes and those involving a considerable handling of materials along with plant maintenance are, however, fields where work study has a proved record of success.

Although the procedures of fundamental design are not amenable to the cruder practices of work study—it is highly desirable that they should be left untouched—there are engineers who need to be reminded that time is valuable, that there are considerable benefits to be derived by rationalising mental efforts and by avoiding a repetition of what has been done before. An ordered mental approach is all the more necessary in these times of acute shortage of technical people. Moreover, almost every live engineer strives to keep up to date with the veritable flood of technical and scientific developments and this means extracting what is useful from a large number of widely-scattered sources; and if some firms provide an information service for its technical staff, this does not remove the need for a conscious attempt to study the literature with the greatest economy in effort.

If work study does not perhaps compare in direct usefulness with other available tools, when it comes to the detailed design of a plant its value cannot be disputed. Its aim in the first place is to devise a flow sheet, and hence a plant, which produces the maximum all-round economy and, in the second, attains this objective with the minimum expenditure of effort and in the shortest time. Determining the layout of the plant, the number and disposition of vessels and the design of the pipework system are helped immensely by its application. The detailed analysis of the operations which a particular design of plant may require, the implications of alternative arrangements and the synthesising of the various operations all result in an understanding of the physical operation of the plant and its labour requirements unobtainable by other methods. It leads to a plant economical to maintain as well as to operate. Models are frequently pressed into use in these studies and have proved especially useful in the design of pipework. This is a very strong point, because piping design is a notoriously expensive item with the majority of complex plants; and not only design, but also the final erection and commissioning of plant are hastened by means of this technique. It is safe to conclude, therefore, that, properly used, and despite its limitation in the sphere of chemical manufacture, it is a tool worthy to be used at many stages of design.

66.0615.

STUDIES IN MASS TRANSFER
PART 2 — LEACHING

by N. J. HASSETT*
B.Sc., Ph.D., M.I.Chem.E.

The author applies the principles outlined in his first article to practical leaching problems

IN the previous paper† it was pointed out that multi-component continuous-mass-exchange processes functioning by virtue of two phases tending towards equilibrium cannot always be equated to a number of theoretical transfer stages, because if diffusion plays a measurable part each constituent will approach equilibrium at a different rate. In such cases there will be a spread away from the constituent distribution as derived using theoretical stages, with the lighter components drawing away from the heavier components because of their faster approach towards equilibrium. The rate of approach was shown to be definable in terms of a time constant particular to each component for a given system.

In the case of countercurrent differential exchange, it was noted that a given length of contact column would be equivalent to different numbers of transfer stages for the various constituents, and that for any given constituent the length of a theoretical transfer stage would depend upon the position in the column. Fig. 1, which was not included in the previous paper,† illustrates this. At P, the theoretical equilibrium concentration of a given component A corresponding to a concentration of x_P in the heavy phase would be $k.x_P$ in the light phase. There is then a driving force $k.x_P - x'_P$ at P which causes the transfer of A from the heavy to the light phase. PQ is a theoretical transfer stage where $x'_Q = k.x_P$, i.e., where the light phase leaving Q is in equilibrium with the heavy phase leaving P. PQ will not be a theoretical stage for other components. Furthermore, since the rate of approach to equilibrium is dependent upon the medium, the length of a transfer stage is unlikely to be the same at all parts of the system.

Design of Extraction Equipment

The practical aspect of this differential approach to equilibrium in extraction is evidenced in certain processes based on experience rather than theory. The extraction of medicinal herbs is a case in point. Another example is that of carobs which contain both sugars and bitter constituents. One extraction procedure produces a syrup which is bitter and repugnant, while another yields a syrup pleasing to the palate. The familiar example of well-brewed as opposed to stewed tea comes to mind.

The preceding considerations may be pertinent in the leaching of multi-component systems which is now playing a more important part in processing.

The design of extraction equipment is basically concerned with the number and size of operating stages for a given extraction duty. Where it is a matter of extracting a principal constituent without regard for minor constituents, the procedure is fairly straightforward. Where it is required to effect the extraction in such a manner that one constituent is preferentially extracted, or left in the residues, and selective solvents are unavailable, it is a matter of decreasing the retention time and hence leaching efficiency in each stage. Since preferential extraction of one component leaves the residues weighted with the others, the method is limited. The spread due to the pull away of the lighter components from the heavier leaves a counteracting composition change behind. The potential field of investigation here, however, both theoretical and experimental, is a wide one.

The Extraction Mechanism

In the simple case, three components are concerned: an insoluble solid, a soluble material and a solvent. A more complex case concerns two or more soluble materials present together.

When dry solid matter containing soluble matter is contacted with solvent, the latter, in penetrating the solid, dissolves the soluble matter and carries it further into the solid as a solution, so that when the solid is finally saturated with solvent there will be a concentration gradient of soluble matter increasing into the solid. This soluble matter diffuses back through the solvent within the solid in accordance with the known laws of diffusion, tending to even out the concentration gradients. Solute reaching the surface of the solid diffuses out into the free liquid, thus maintaining the concentration gradients within the solid and the process tends to continue until there is a uniform concentration of solution throughout the system. In practice, equilibrium will not be obtained and there will be a higher average concentration of solution in the solid than in the free liquid at the time when the free liquid is separated from the wet residues. If the wet separated residues are now contacted with a solution of lower concentration, or fresh solvent, the diffusion process is resumed.

The following factors will speed up the primary leaching process:

(i) Opening up the solid by grinding or shredding to shorten the diffusion path. This treatment may also break open cells otherwise impermeable to solvent.

(ii) Use of low viscosity solvent, reducing diffusion resistance.

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† *British Chemical Engineering*, 1958, 3, 66-71.

(iii) Extraction at as high a temperature as practicable, serving the double purpose of decreasing viscosity and increasing the mobility of the solute.

(iv) Agitation to augment diffusion into the free liquid.

In some cases, the solid may be opened up by heat treatment, as in the case of some minerals. A heat treatment of certain oilseeds, for instance cottonseed, serves to break open the oil cells, but in other cases heat treatment must be avoided. In the case of soya, the proteins would be coagulated and extraction hindered.

The primary leaching is followed by separation of free liquid from the wet solid, and apart from possible entrainment, there are two main efficiencies bound up in the overall extraction efficiency of a stage.

Primary Leaching Efficiency

The primary leaching efficiency in a stage n can conveniently be expressed as c'_n/c_n, where c'_n is the concentration of the free liquor leaving the stage and c_n is the average concentration of the liquor bound up with the solids leaving the stage after separation from the free liquor. The approach to equilibrium in a stage, which is a measure of the leaching efficiency, must not be confused with the actual leaching efficiency. The equilibrium approach is given by $(c_1 - c_2)/(c_1 - c_E)$, where c_1 and c_2 are the average concentrations of the solution within the solid matter when leaching begins and when the leached solid has been drained. In the case where dry solid enters a stage, c_1 is considered as the concentration when the solid is just saturated with the solution in the stage and no diffusion out of solute has commenced. If two solutes are present each will have its own approach to equilibrium and hence leaching efficiency.

In a very general manner, all the factors opposing equalisation of concentration can be lumped into a resistance term R in a given stage. The primary forcing factor is the concentration differential between occluded liquid and free liquid. Following the argument of the previous paper, this factor can be taken as $(c - c')$, where c and c' are concentrations of occluded and free liquor. Then,

$$\text{Rate of Leaching} = \frac{\text{Driving force}}{\text{Resistance}}$$

$$dc'/dt = dc/dt = (c - c')/R \qquad \ldots\ldots \text{(i)}$$

If c_E is the equilibrium concentration and r is the ratio of free to occluded liquor (extraction ratio), then by a material balance:

$$(c - c') = (c_E - c')(r + 1) \qquad \ldots\ldots \text{(ii)}$$

and substituting in (i):

$$dc'/dt = (c_E - c')(r + 1)/R \qquad \ldots\ldots \text{(iii)}$$

Integrating and rearranging gives:

$$c' = c_E - (c_E - c'_o)\, e^{\frac{-(r+1)t}{R}} \qquad \ldots\ldots (7)$$

$$\text{and } c = c_E + r(c_E - c'_o)\, e^{\frac{-(r+1)t}{R}} \qquad \ldots\ldots (7a)$$

$$\text{or } c = c_E + (c_o - c_E)\, e^{\frac{-(r+1)t}{R}} \qquad \ldots\ldots (7b)$$

These equations give an indication of where to look for design constants in scaling up, and in leading to values of c'_n/c_n in relation to contact time, and hence plant capacity, with regard to the number of extraction stages (as indicated later).

Separation Efficiency

In continuous countercurrent stage extraction, the solid matter is separated from free solution between stages and conveyed from stage to stage in sequence. In continuous countercurrent differential extraction, free solution moves away from the solid it has just leached and a weaker solution takes its place. In either case, the separation efficiency as distinct from the leaching efficiency is determined by the quantity of solution which remains associated with the solid matter.

In the stage process, separation efficiency increases with time of draining and will be markedly increased if interstage centrifuging or expression can be employed. In the case of differential extraction, separation efficiency partly rests with even flow distribution (absence of channelling) and partly with the time factor or speed of flow. Separation efficiency is of prime importance due to its bearing on the extraction ratio.

Plant Size and Extraction Efficiency

The relation between plant size and extraction efficiency was discussed in the previous paper and a worked example given. For a given degree of extraction, the number of stages required will be more as the extraction efficiency is less. The balance between number and size of extraction stages is then a question of economy. For a given throughput and approximate-end conditions, leaching efficiency is a matter of contact time and, hence, holding capacity. Often, a far great improvement in processing can be obtained by attention to separation efficiency rather than to primary leaching efficiency.

Determination of Number of Stages and Operating Data

The usual arithmetical or graphical methods of solving extraction problems are based on the assumption that solute and solvent are distributed as a solution of uniform concentration throughout an extraction stage; the composi-

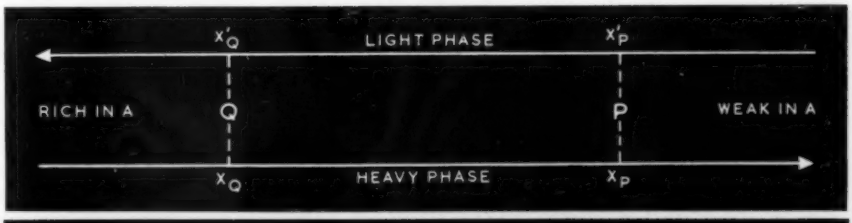

Fig. 1. Definition of a transfer stage in a countercurrent differential mass-exchange process.

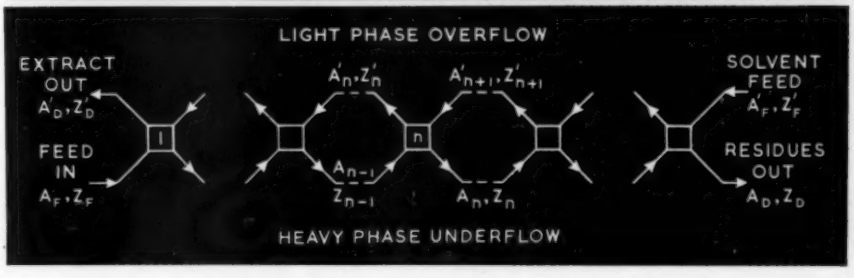

Fig. 2. Definition of a typical problem in multi-stage countercurrent extraction, with symbols.

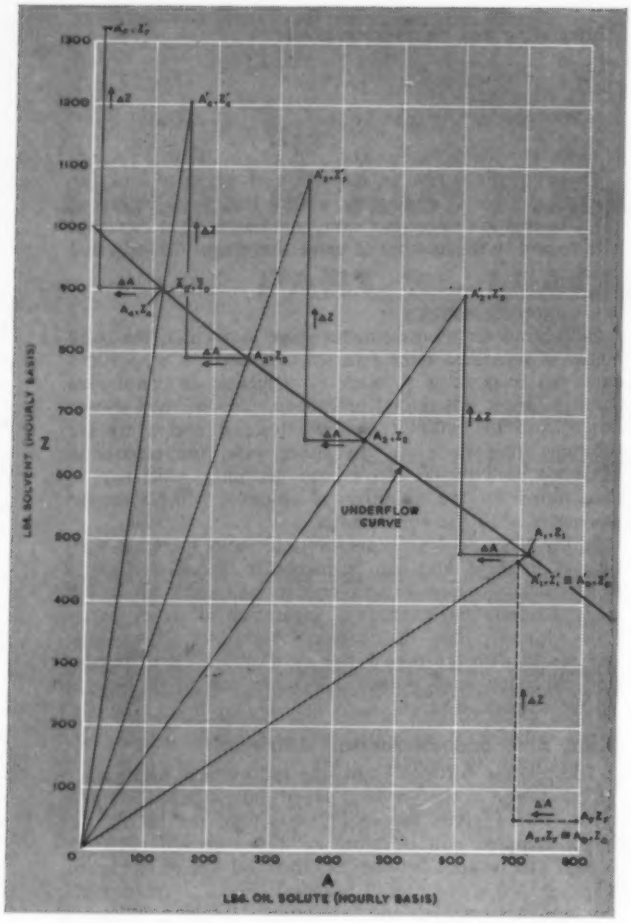

Fig. 3. Graphical solution to problem of extracting oil from meal by benzene countercurrentwise.

tion of the liquid occluded by the solid is thus assumed to be identical with that of the free liquid leaving the stage. Allowance is made for extraction inefficiency by an overall multiplication factor.

Arithmetical methods of solution do not lend themselves readily to analysis of systems where both the quantity of solvent, and that of solution retained by unit quantity of insoluble matter, vary from stage to stage. These cases respond more easily to graphical analysis and a number of such methods are described in the literature. The actual graphical construction in some of these is quite simple and quick, although the underlying theory may be more complex.

The graphical method now described, which is an extension of the basic method described in the earlier paper, is simple both in underlying theory and its application. It also has the advantage of working in absolute quantities, giving direct information on the flow quantities at all parts of the system.

To avoid ambiguity, the solute will be denoted by A and the solvent by Z. Fig. 2 illustrates a multi-stage extraction process, the A and Z quantities being the actual flow quantities in unit time. The insoluble solid is only a carrier of the underflow and can be regarded as a chain of buckets carrying the occluded liquor in the residues from stage to stage.

The usual problem can be resolved to the following form. "On an hourly basis, a given quantity of insoluble matter, say M lb., carrying A_F lb. of solute and Z_F lb. of solvent (total weight $M + A_F + Z_F$) is to be extracted using an initial mixture of Z'_F lb. of solvent: A'_F lb. of solute. Not more than A_D lb. of solute are to be left in the final residues." The information usually required is the number of stages, the end concentrations and quantities.

The available data are the quantities of solution held in the insoluble solid at different solution concentrations.

It is not generally appreciated how misleading such data can be, unless they are obtained under conditions which simulate closely those at the actual plant. Furthermore, the amounts of each component held in the solid should be ascertained, since the assumption that the average concentration of solution held in the solid is the same as that of the free liquor may be far from correct. This will be appreciated from the later discussion.

The two basic relationships employed in the graphical method now described are:

(a) There can be no accumulation or depletion of any constituent within the system. The net transfer of any component per hour must therefore be constant. Reference to Fig. 2 gives the following relationships, taking positive flow from right to left.

$$A'_D - A_F = A'_n - A_{n-1} = A'_{n+1} - A_n = \triangle A'_F - A_D = \triangle A \quad \ldots\ldots \text{(i)}$$

$$Z'_D - Z_F = Z'_n - Z_{n-1} = Z'_{n+1} - Z_n = Z'_F - Z_D = \triangle Z \quad \ldots\ldots \text{(ii)}$$

(b) If equilibrium be assumed at each stage, then:

$$\frac{A'_n}{A_n} = \frac{Z'_n}{Z_n} \quad \ldots\ldots \text{(iii)}$$

If the primary leaching efficiency in stage n is E_n, then

$$\frac{A'_n}{A_n} = \frac{E_n Z'_n}{Z_n} \quad \ldots\ldots \text{(iiia)}$$

Relationship (a) is the link between underflow $n - 1$ and overflow n, while relationship (b) is the link between overflow n and underflow n. Using these links in sequence, a multi-stage extraction system can be evaluated.

This is best illustrated by worked examples and the first chosen problem is one that has been stated to be the most often solved in the literature on solid-liquid extraction.

Worked Example on Counter-current Extraction

Oil is to be extracted from meal by means of benzene, using a continuous counter-current extractor. The unit is to treat 2000 lb. of meal (based on completely exhausted solid) per hour. The untreated meal contains 800 lb. of oil and 50 lb. of benzene. The fresh wash solution consists of 20 lb. of oil dissolved in 1310 lb. of benzene. The exhausted solids are to contain not more than 120 lb. of unextracted oil. Experiments carried out under conditions identical with those of the projected battery show that the solution retained by the solid depends on the concentration of the solution, as shown in Table 1. Find:

(a) The composition of the strong solution.

(b) The composition of the solution adhering to the extracted solids.

(c) The weight of the solution leaving with the extracted meal.

(d) The number of units required.

Solution

The data are given in the first two columns of Table 1, and from them the values of A and Z have been derived on the basis of the hourly throughput of 2000 lb. insoluble matter.

These values give the underflow curve in Fig. 3. It will be noted that here there is an inherent assumption which must apply to all methods of solution where the data are limited. This is that the composition of solution retained by the solid is the same as that of the free solution, i.e., $E_n = 1$ for all stages.

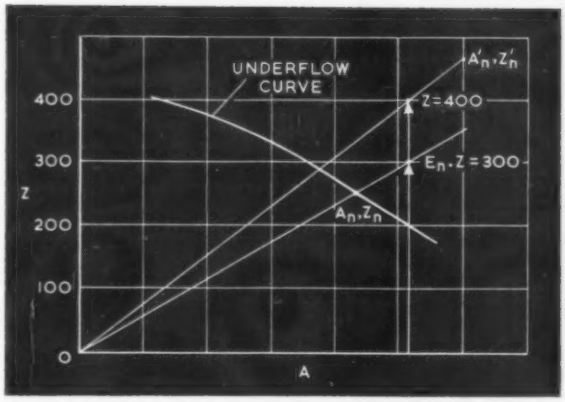

Fig. 4. Graphical solution for number of actual stages required in a stagewise extraction.

TABLE 1

Solution composition, lb. oil/per lb. solution	*Weight of solution (lb.) retained by 1 lb. solid*	*Oil retained in 2000 lb. solid*	*Solvent in 2000 lb. solid*
x	w	$A=2000.x.w$	$Z=2000(1-x)w$
0.0	0.500	0 lb.	1000 lb.
0.1	0.505	101 „	908 „
0.2	0.515	206 „	824 „
0.3	0.530	318 „	741 „
0.4	0.550	440 „	660 „
0.5	0.571	571 „	571 „
0.6	0.595	714 „	476 „
0.7	0.620	868 „	372 „

The overall balances can now be made and preliminary end values derived. Assuming the limiting extraction conditions to obtain, we have as data.

Meal Feed	*Solvent Feed*	*Residues Out*
A_F = 800 lb.	A'_F = 20 lb.	A_D = 120 lb.
Z_F = 50 lb.	Z'_F = 1310 lb.	

From the underflow curve, Z_D is read as = 892 lb. From overall balances.

$$Z'_D = Z_F + Z'_F - Z_D = 50 + 1310 - 892 = 468 \text{ lb.}$$
$$A'_D = A_F + A'_F - A_D = 800 + 20 - 120 = 700 \text{ lb.}$$

All the end quantities are now known and the points A_F, Z_F, A_D, Z_D, A'_F, Z'_F and A'_D, Z'_D are located on the graph. The $\triangle$ quantities can now be derived.

$$\triangle A = A'_D - A_F = 700 - 800 = -100 \text{ lb.} \quad \ldots . \text{(i)}$$
$$\text{check } A'_F - A_D = 20 - 120 = -100 \text{ lb.}$$
$$\triangle Z = Z'_D - Z_F = 468 - 50 = 418 \text{ lb.} \quad \ldots . \text{(ii)}$$
$$\text{check } Z'_F - Z_D = 1310 - 892 = 418 \text{ lb.}$$

The solution is now followed on the graph, noting that A_F, $Z_F \equiv A_o$, Z_o and A'_D, $Z'_D \equiv A'_1$, Z'_1 (see Fig. 2).

It is possible to start from any end phase and derive the answer, but for reasons that will be apparent it is preferable to commence with the solid feed.

A_F, Z_F is first located. $\triangle A$ is then added to this point by graphical addition taking account of the negative sign, followed by the addition of $\triangle Z$. This gives the point A'_1, Z'_1 from the origin A_o, Z_o. We have gone from the heavy phase or underflow $n-1$ to the light phase or overflow n.

Correspondence of the derived point A'_1, Z'_1 with the values of A'_F, Z'_F is a check that the distances $\triangle A$ and $\triangle Z$ are correct. From now on these additions can conveniently and with certainty be marked off by dividers.

To arrive at A_1, Z_1 from A'_1, Z'_1 (i.e., A_n, Z_n from A'_n, Z'_n) relationship (b) is used. If a line is drawn from the origin through A'_1, Z'_1, all the points on that line will represent solutions of that same composition and the point where it cuts the underflow line must be A_1, Z_1.

The construction is repeated. $\triangle A$ and $\triangle Z$ are added to A_1, Z_1 leading to A'_2, Z'_2. The line joining this point to the origin cuts the underflow line in A_2, Z_2. Following the construction, it is found that the fourth stage just overruns the end point A_D, Z_D written as $\overline{A}_D$ $\overline{Z}_D$. The solvent feed, as can be seen by referring to Fig. 2 is from a non-existent stage ahead, and following the construction a step further A'_F, Z'_F is reached. The required information can then be read from the graph.

(a) The strong solution is A'_D, Z'_D and is 700 lb. oil plus 460 lb. benzene per hour. $C'_D = \dfrac{700}{1160} = 0.604$ or 60.4%.

(b) $C'_D = \dfrac{118}{1018} = 0.116$ or 11.6%. The solution adhering to the extracted solids is (c) A_D, Z_D, i.e., 118 lb. oil ; 900 lb. benzene per hour. (d) Four theoretical stages are required.

It was observed earlier that the data given were inadequate for reliable design purposes. The full data should have given the actual amounts of solvent and of solute retained by the solid. This would have given the true operating conditions and the values of E_n as defined under relationship (b).

In the theoretical stage construction, the A_n, Z_n points have been located where the line with slope Z'_n/A'_n cut

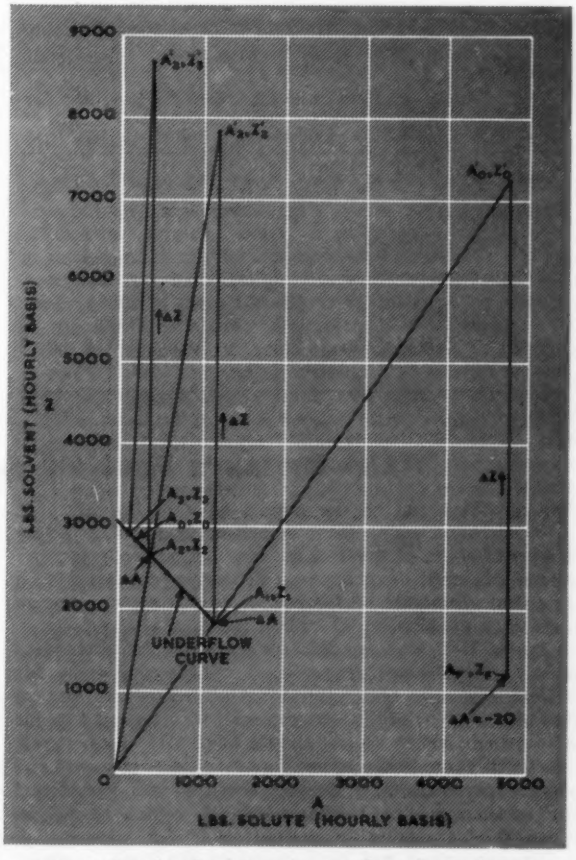

Fig. 5. Graphical solution for number of actual stages in an example previously worked out for iterative extraction.

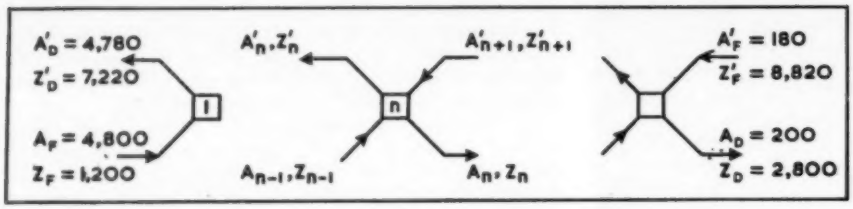

Fig. 6. Statement of a problem in countercurrent extraction previously carried out in an iterative manner.

the underflow line. For actual stages, the points would be located where lines with slopes $E_n.Z'_n/A'_n$ cut the underflow line. The graphical construction for this is simple. The origin is joined to A'_n, Z'_n as before and where this line cuts any convenient Z abscissa with a round number such as $Z = 400$, this is multiplied by E_n, say $=0.75$, and marked below on that same ordinate. A line through the original and the point $Z = 300$ now has the slope $E_n.Z'_n/A'_n = Z_n/A_n$ and where it cuts the underflow line is the corrected required point. The construction is shown in Fig. 4. The effect is to increase the number of stages.

Worked Example Countercurrent Compared with Iterative Batch Extraction[1]

In a recent paper, an example calculation was given of an iterative batch extraction and compared with graphical methods of solution. The extraction process was the following. A solid comprising 6000 lb. inert matter, 4800 lb. solute and 1200 lb. solvent is extracted with successive batches of 3000 lb. of 2% solution (composition 2940 solvent, 60 solute). When drained, 1 lb. of the inert solid retains 0.5 lb. solution at all concentrations.

It was shown that after five contacts the combined extracts would provide 18,000 lb. of miscella at 27% concentration, while the solid residues would retain some 220 lb. of solute.

The problem will now be examined to see how this performance compares with countercurrent stage extraction. The solubility of the solute was given as 40%, so a concentration just below this will be taken for the extract, and a figure of 200 lb. for the solute retained in the residues.

TABLE 2.—Underflow Quantities.

Note. Weight of underflow is constant at 3000 lbph.

Concentration.	*Quantity per unit time*	
lb. solute/lb. soln.	*A* lb.	*Z* lb.
0.0	0	3000
0.1	300	2700
0.2	600	2400
0.3	900	2100
Limit 0.4	1200	1800

The underflow values will first be derived, and the problem will consider the throughput of 12,000 lb. feed (i.e., 6000 lb. inerts) per unit time.

Solids discharge if $A_D = 200$ lb.

$$Z_D = 3000 - 200 = 2800 \text{ lb.}$$

(since $A_n + Z_n = \text{const.} = 3000$ lb. (data))

Overall balances. Take an input of 9000 lb. solvent feed (i.e., 8820 lb. solvent, 180 lb. solute).

$$A'_D = A_F + A'_F - A_D$$
$$= 4800 + 180 - 200 = 4780 \text{ lb.}$$
$$Z'_D = Z_F + Z'_F - Z_D = 1200 + 8820 - 2800 = 7220.$$

$$\text{Final Miscella Concentration} = \frac{A'_D}{(A'_D + Z'_D)} = \frac{4780}{4780 + 7220}$$

just below 40%.

$$\triangle A = A'_D - A_F = 4780 - 4800 = -20 \text{ lb.}$$
$$\text{check } A'_F - A_D = 8180 - 200 = -20 \text{ lb.}$$
$$\triangle Z = Z'_D - Z_F = 7220 - 1200 = 6020 \text{ lb.}$$
$$\text{check } Z'_F - Z_D = 8820 - 2800 = 6020 \text{ lb.}$$

The solution is now followed on the graph. The same construction is followed as in the previous example. The $\triangle A$ value is too small to be significant on the graphical construction. Three stages suffice to overrun the required end value, giving the solute retained with the residues as less than 200 lb. The comparative figures are tabulated below.

TABLE 3.—Comparison of Two Extraction Processes.

	Iterative Extraction	*Countercurrent*
Number of changes or stages	5	3
Total quantity of solvent used	15,000 lb.	9000 lb.
Final miscella	27%	40%
Solute retained in residues ...	225 lb.	$\ll$ 200 lb.

REFERENCE
[1] Davis, D. S. *Brit Chem. Eng.*, 1957, **2**, 662.

Britain's First Underground Gas-holder

IT is hoped that by the middle of 1958 Britain's first underground gas-holder in a rock-salt bed 1200 ft. below the north shore of the Tees estuary will be ready for use. When this cavern is complete and working the gas will be stored at a pressure of 450 psi corresponding to a storage capacity equivalent to 10 million cu. ft. of coal gas.

In the last three annual reports of the Northern Gas Board there have been references to preparations for storing gas in an underground cavity but the first project foundered when drilling operations had progressed to the stage where a bed of salt should have been encountered. The rock formation was not found to be as expected and no salt was present. A further borehole was started and this encountered a thickness of salt which would be adequate for making the desired cavity.

The first plans had been based on the use of existing cavities produced by pumping brine from the salt measures in the Port Clarence area. However, after consultation between the Gas Board and Imperial Chemical Industries Ltd., it was decided that it would be unsafe to do this in cavities which had been developed without any precautions being taken regarding their shape. I.C.I. therefore undertook to develop a new cavity whose shape would be carefully controlled and which would be suitable for gas storage. The cavity which was planned—and should now result from this second and apparently successful drilling—will measure 10,000 cu. m (35,000 cu. ft). It will be necessary, in due course, for the Northern Gas Board to provide a compression station at the Port Clarence brine field to supply the gas at the desired pressure and gas supply lines will be necessary which will lead from Haverton Hill to the brine field. Recently, Dr. R. N. Kerr, works manager of the I.C.I. Cassel Works, reported that the cost of the scheme was very heavy, but that the Gas Board is satisfied that there are substantial capital savings compared with conventional storage.

620.19; 374

TEACHING CORROSION SCIENCE

Observations on a recent meeting of the S.C.I.'s Corrosion Group*

THE Corrosion Group of the Society of Chemical Industry has, since its formation seven years ago, been responsible for the introduction of corrosion as a subject into many examination syllabuses. Its Education Panel has always been active in promoting special courses and recommendations to teaching bodies upon the treatment best given to the subject. A measure of its success is that in a document issued by the panel in December over forty universities and colleges are listed as providing some type of instruction in corrosion. It was therefore both timely and useful that the Group held a discussion on the teaching of corrosion science at the headquarters of the S.C.I. on December 18 last. Under the chairmanship of DR. S. G. CLARKE, the discussion was divided into two sections, dealing with existing facilities and future requirements respectively, and each session was opened by a brief statement from an officer of the Group.

MR. L. W. STUBBS (honorary secretary of the Group Education Panel) outlined the pattern of existing instruction in corrosion, showing how this ranged from the provision of short courses for industrialists to representation of the subject in various examination schemes suggested by academic and professional bodies. In the discussion which followed the point was repeatedly made that training in corrosion science should only be introduced in undergraduate courses, and that the main study should be postgraduate, and particularly by means of postgraduate research. It was shown, however, that the subject is now appearing in more engineering and metallurgy degree schemes, and also that the Royal Institute of Chemistry accepts the subject as one in which its Diploma may be awarded.

The second discussion was prefaced by an address by DR. T. P. HOAR (chairman of the Group Education Panel), who took as his theme the future needs for training in corrosion. DR. HOAR thought that the subject could well be introduced into grammar-school chemistry courses, and particularly that some of the demonstrations suggested by DR. U. R. EVANS should be given to sixth forms.

In teaching corrosion seriously in undergraduate courses, DR. HOAR felt that the standards in thermodynamics, kinetics and electrochemistry required to tackle the subject were high enough to produce difficulties if corrosion was introduced too early. This also meant, in his experience, that it was almost impossible to provide similar instruction for engineers, whose basic chemistry was much too weak. In dealing with the type of course to be provided, DR. HOAR felt that the practical aspects of the subject were too complicated for this purpose, and that available lecture time was best spent upon the fundamental electrochemistry involved in corrosion processes. On this latter point also he felt that there was room for mutual education between those engaged in corrosion work in industry, research associations, colleges and universities, for there was a tendency for practical short-term work and fundamental inquiries to proceed without reference to each other.

In the resulting discussion, several speakers reiterated the view that engineers were in general unpromising material for training as "corrosionists", and that chemists or metallurgists were better able to adapt themselves to such studies, particularly at postgraduate level. There was some discussion as to the place of the short evening course delivered by a succession of specialists, as is often proffered by colleges of technology. Some felt that the varied nature of the audience, as well as a lack of cohesion between the individual lectures, rendered these of dubious value, whilst others thought that such courses at least spread an awareness of corrosion problems.

To a chemical engineer reporting the conference, at least two points were very striking. First, the general attitude of the conference that corrosion was mainly a chemical and metallurgical problem ideally considered as removed from practical complications. Chemical plants suffer from intensive corrosion, and often are protected at some commercial level rather than freed completely from such depredations. Again, the attack is often localised and selective, and the process conditions are as important as those stated in the ideal representation of the chemical problem involved. The metallurgical history of the materials of construction is, of course, of importance, but this in turn can only be appreciated from a knowledge of the design and fabrication methods to be used. In the chemical industry (where ideally dilute solutions have little commercial interest) there would seem to be a need for an engineer able to evaluate corrosive situations, and to select suitable materials, together with optimum operating procedure.

The second point was the almost unanimous view that engineers were so poorly equipped with chemical (and especially physical chemical) knowledge as to be incapable of tackling corrosion work. It does seem that chemical engineers are really in a unique and favourable position here, for they have not only a width of training which particularly fits them for this task, but they are engaged in that industry where the problem is most acute.

In the majority of present-day chemical engineering degree courses the chemical training is at least the equivalent of ordinary degree level, and selected engineering subjects are taken to a similar stage before chemical engineering studies begin. Some study of corrosion with special reference to materials selection for plant construction would not appear out of place; indeed, such an important aspect of chemical plant design and operation can hardly be ignored.

Chemical engineers also can recall that only twenty years ago there existed a very impressive body of opinion which held that it was quite impossible to study chemical engineering at anything but postgraduate level. Almost parallel arguments as to those expressed at this discussion were in fact advanced in support of this view. But now a first degree in the subject is accepted, and the subject is studied in the first year at university. Although this may never be the situation with corrosion science, at least the moral would appear to be that the subject will ultimately find a place in some undergraduate courses—probably in chemical engineering departments. In this connection it is noteworthy that corrosion is now an optional subject in the final year of the B.Sc. Tech. in chemical engineering at Manchester, and that an active research group there is engaged on problems arising in chemical industries.

* **Dr. T. K. Ross,** *who sent us this report, is the Senior Lecturer in Chemical Engineering, Faculty of Technology, University of Manchester.*

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INDUSTRIAL EXPLOSION PROTECTION

Explosions may be controlled by suppressants, venting, advance inerting or isolation. These techniques are discussed and their practical use in plant protection illustrated

by D. W. MEREWOOD, A.M.I.Mech.E.

THE technique of explosion suppression is possible because an explosion is not an instantaneous occurrence, but requires a definite time from the instant of ignition to the development of maximum pressure. By rapidly introducing suppressant, it is possible to quench the explosion flame in the very early stages of its growth, thus preventing a dangerous increase in pressure. When suppressing ideal petrol/air mixtures the final pressure does not exceed 3 psig when the initial pressure is 1 atmosphere.

At any instant during the growth of an explosion, the pressure relative to the maximum pressure is proportional to the amount of combustible mixture that has been burned. The maximum pressure that can be developed from an ideal petrol/air mixture at 1 atmosphere is 105 psig and a suppression system designed to prevent the final pressure exceeding 3 psig must therefore ensure that not more than 3% of the mixture is burned. The flame speed during the early stages of an ideal petrol/air explosion is about 15 ft/sec., which is slow compared with the velocity of 200 ft/sec., at which the suppressant is injected. Provided an explosion is detected sufficiently early, it is therefore possible to quench the explosion flame before more than 1 to 3% of the mixture has been burned.

An explosion detector can be either of the pressure- or light-sensitive type, but on the majority of industrial plants the pressure-sensitive type is used. This type of detector will operate when either a predetermined rate of pressure rise (10 psi/sec.), or static pressure (0.5 psig) setting, is exceeded. This combination of settings ensures the earliest possible detection of an explosion, whether it be fast or slow. In ideal petrol/air mixture explosions, the detector will operate on the rate of rise setting which corresponds to an explosion pressure of only 0.2 psig. As the pressure waves associated with an explosion travel at about 1000 ft/sec., it will be appreciated that the time lag between the instant of ignition and detection is very small. In the case of a 1000-gal. vessel, this time lag would be about 35 m sec., and Fig. 1. illustrates the sequence of events when

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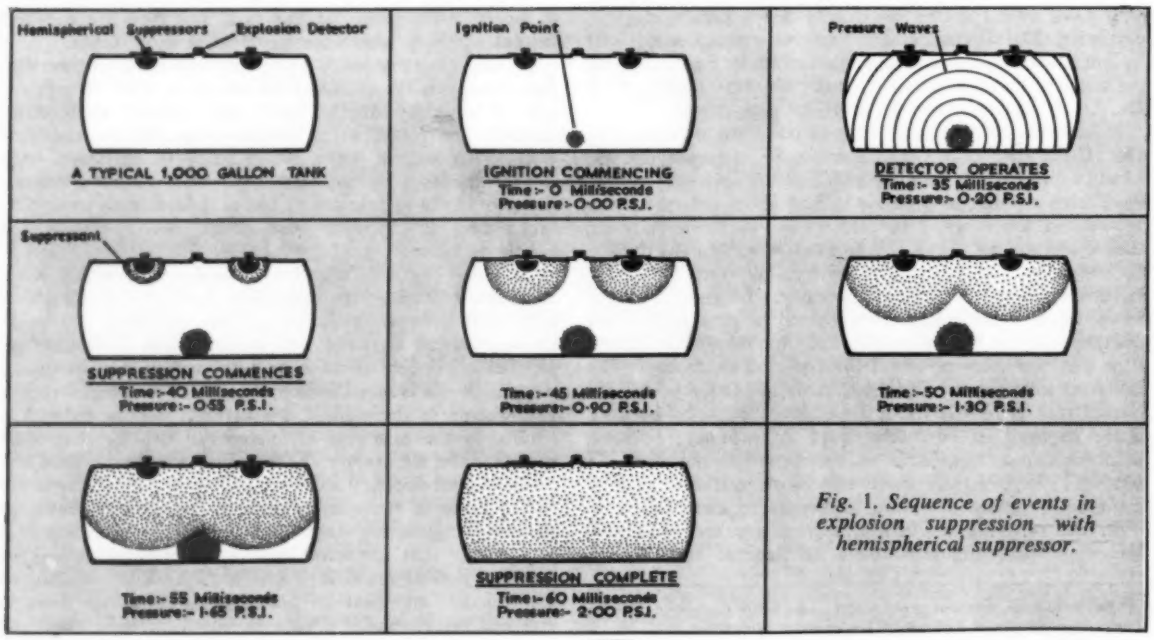

Fig. 1. Sequence of events in explosion suppression with hemispherical suppressor.

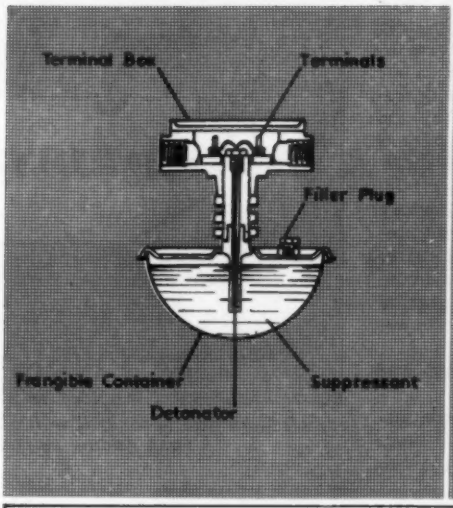

Fig. 2. Hemispherical suppressor.

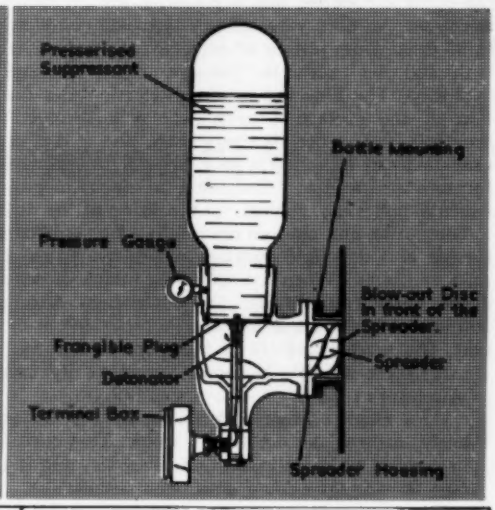

Fig. 3 (right). High-rate discharge bottle.

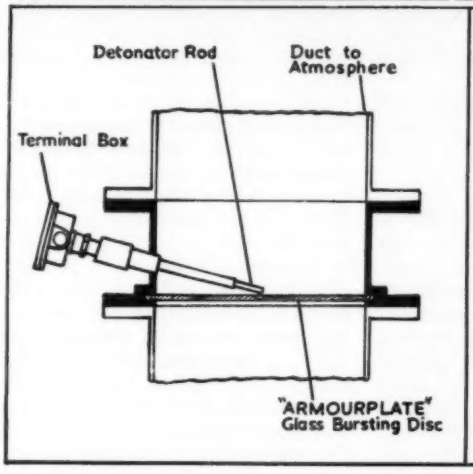

Fig. 4. Detonator-operated "Armourplate" glass bursting disc.

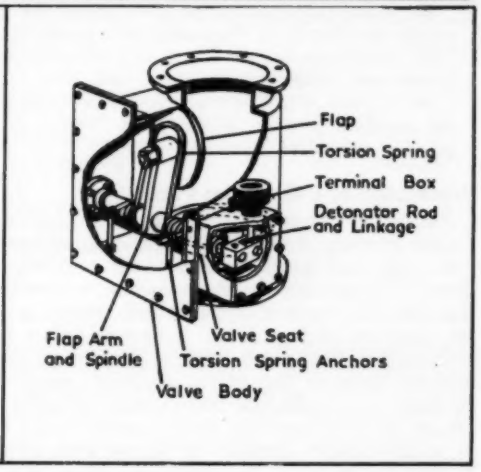

Fig. 5 (right). High-speed isolation valve.

suppressing an explosion in a vessel of this volume. In this case, the time taken from the instant of ignition to the completion of suppression is only 60 msec., and the increase of pressure only 2 psi.

The suppressors shown in operation in Fig. 1 are of the hemispherical type as illustrated in Fig. 2; the suppressant normally used is chlorobromomethane. When the detonator located at the centre of the hemisphere is fired, the shock waves rupture the hemisphere and the suppressant is ejected at about 200 ft/sec. Where it is not possible to use hemispherical suppressors, for example in cyclones where they would interfere with the efficient operation of the plant, the 3-in. high rate discharge bottle can be used. These bottles are mounted externally to the plant and one is illustrated in Fig. 3. The bottles contain suppressant pressurised with nitrogen to 250 psig. The suppressant is ejected when the sealing device is fractured by the firing of a detonator located inside the elbow of the bottle.

Other Methods of Protection

Explosions can be controlled by other methods than suppression, and venting is very often employed. By correctly proportioning and positioning vents, it is possible to prevent the explosion pressure exceeding 1 psig. When it is essential that the vents should fully open at a very low pressure, conventional bursting discs are not suitable. Where simple blow-off panels cannot be used, the detonator-operated "Armourplate" glass bursting disc provides a very efficient explosion vent. This type of bursting disc, illustrated in Fig. 4, consists essentially of a sheet of "Armourplate" glass which is shattered by firing a detonator located about $\frac{1}{4}$ in. from the surface of the glass. On fracture, this glass does not splinter, but disintegrates into small particles, making it ideal for this application. The operation of the "Armourplate" glass bursting disc is initiated, as in the case of suppressors, by means of an explosion detector.

Venting is a method which is particularly suitable for large volumes of about 20,000 gal. and over. It must be remembered, however, that with a venting system there is the possibility of a following fire, and the plant should therefore be automatically inerted with CO_2 or some other suppressant.

Where a number of sections of plant are connected by ducting, it is sometimes necessary to prevent an explosion propagating from section to section. By introducing suppressant ahead of the flame front, the explosion can be confined to the section of the plant where it originated. This technique is known as advance inerting and is effected by means of either hemispherical suppressors or high rate discharge bottles.

As an alternative to advance inerting, isolation can be employed and a high-speed isolation valve, shown in Fig. 5, can be used for this purpose. The valve is held in the open position by means of a catch, inside which a detonator is located. When the detonator is automatically fired,

the catch is ruptured and a powerful torsion spring closes the valve. An 8-in. valve of this type will completely close in 80 msec. from instant of detection and can, if necessary, withstand the maximum pressure of an ideal petrol/air explosion. The time lag between detection and the operation of the protection equipment is determined by the time required to fire the detonators, and if d.c. current is used this can be reduced to 1 msec. The system is thereforefore arranged to incorporate an electrical power unit, which supplies d.c. current for the firing of the detonators.

The power unit consists essentially of a step-down transformer and dry-plate rectifier, which maintains a charge on a condenser. When the detector contacts close, the condenser discharges through the detonators. A number of features and safeguards are also incorporated in the power unit. The most important of these are as follows:

(1) stand-by dry batteries automatically come into operation in the event of a mains failure;

(2) a small current of about 2 mA is bled continuously through the detonator circuit. This current holds in a relay which falls out and gives warning if the voltage fails or the system goes open circuit;

(3) a key is provided which isolates the detonator circuit so that it is impossible to operate the system. This key is intended for use during maintenance periods to prevent fortuitous operation; and

(4) a plant shut-down relay can be associated with the electrical system of the plant to shut down fans, grinders and other plant automatically.

Protection of a Grinding Plant

Fig. 6 shows an explosion-protection system for a typical grinding plant. The cyclone is suppressed by two 3-in. high rate discharge bottles and one 500-c.c. hemispherical suppressor. In the majority of installations of this type the grinders are sufficiently strong to withstand the explosion pressure and it is only necessary to locate a ¾-in. high rate discharge bottle at the inlet of the grinder. The operation of this bottle completely inerts the plant between the grinder and the cyclone and prevents a following fire or a re-strike. It also removes any possibility of smouldering material being passed back into the feed hopper by means of the rotary gate valve. Although the suppression equipment on the cyclone would prevent the pressure exceeding more than 3 psi, it would still be necessary to fit a rotary gate valve at the outlet of the cyclone to prevent small quantities of smouldering material being ejected. This particularly applies in the event of an explosion being initiated near the outlet of the cyclone. The high rate discharge bottle located immediately after the cyclone rotary gate valve would extinguish any small quantities of material which might pass the valve before it came to rest.

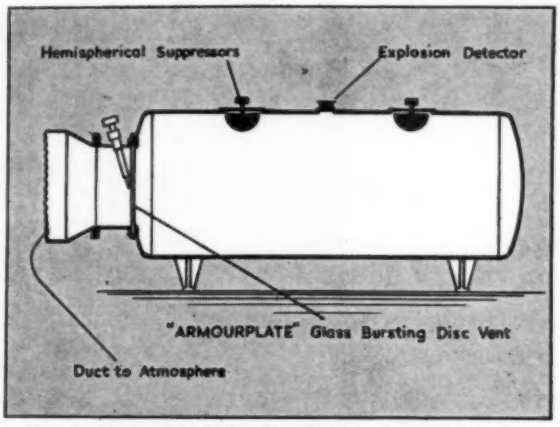

Fig. 7. Storage tank fitted with both suppression and and venting equipment.

It has been found that explosions do not generally start in bag filters, but are caused by a flame front from some other section of the plant. The above protection system is therefore designed to prevent this propagation by means of a high-speed isolation valve and a ¾-in. high rate discharge bottle. It is generally not possible to suppress explosions in bag filters, but to give protection against this fairly remote possibility it is necessary to provide an adequate vent. As in all venting systems, the plant should be automatically inerted to prevent a following fire. The electrical power unit associated with this protection system would be connected to the control system of the plant to shut down the grinder and rotary gate valves.

Fig. 7 illustrates a storage tank fitted with both suppression and venting equipment. In practice, this would not generally be necessary unless the tank was of very weak construction and would be incapable of withstanding the small increase of pressure associated with the suppression of an explosion. In the majority of cases, therefore, it is only necessary to fit a tank with either a venting or a suppression system.

In a paper of this length it is not possible to mention every application and, in addition to those in grinders and storage tanks, systems have been installed on pulverised-fuel plants, spray driers, pneumatic conveying systems, bucket elevators and dust-extraction systems.

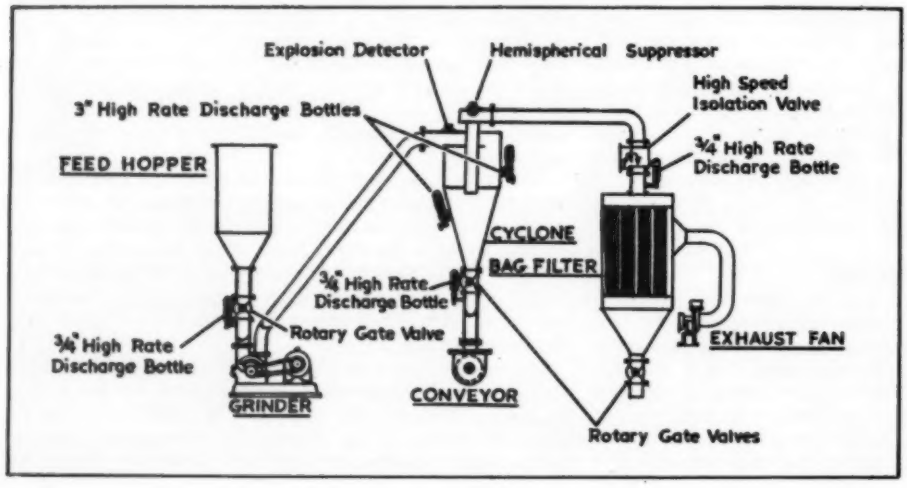

Fig. 6. Explosion protection system for grinding plant.

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INSTRUMENTING A CHEMICAL PLANT

How a chemical plant contractor approaches the problem of integrated process control schemes is the subject of this article*

by E. R. HILL, B.Sc. (Eng.), A.M.I.E.E., A.M.I.Mech.E.

MANY of the processes which are carried out today, requiring extremely high purity products, would be practically impossible to operate without a high degree of automatic control. The importance of instruments, therefore, far outweighs their relative cost compared to that of a chemical unit. In many well-instrumented plants the cost may be no higher than 5% of the total. Suitable control schemes for three different stages of a chemical process are described below.

Typical Control Systems

FURNACE CONTROL

Fig. 1 shows a diagram of the controls for a typical box-type furnace with a radiant and convection system and burners on the end walls with a longitudinal dividing wall running between the two end walls.

The main furnace control consists of a temperature controller connected in the process outlet line from the furnace and actuating a control valve in the fuel gas line to the burners.

If the fuel gas supply pressure to the furnace is liable to fluctuate, it is desirable to correct this as soon as a change in pressure occurs. This is preferable to waiting for the pressure change to cause a heat input change and eventually give a change in output signal from the temperature controller. This is shown by a simple cascade system, in which the output from the temperature controller acts on one side of the diaphragm of a pressure-balanced valve in the fuel gas line, with the other side of the diaphragm connected to the fuel gas line downstream of the control valve. A pneumatic ratio relay is usually introduced between the temperature controller output and the pressure-balanced valve, so that the operating range of gas pressure at the burners can be different from the output pressure range from the controller. The relay will also act as a volume booster, and will prevent fuel gas from flowing back to the control room should a leak occur in the control valve diaphragm. A more elaborate control would be to provide a flow controller in the fuel gas line, again reset by the temperature controller.

This would have the advantage that automatic compensation would be made for the partial plugging up of the burner nozzles, but the extra expense is not usually warranted unless a very dirty fuel is being burned. If fuel oil is being burned as well as gas, it is desirable to fire the furnace with a fixed amount of fuel oil under simple pressure control, with the automatic temperature control operating the fuel gas. This system, of course, requires enough gas to be available to give control over the required load range, and if this is not so it will be necessary to apply the automatic control to the fuel oil instead of the gas. Wide variations in load, due to a planned change in throughput, will normally be covered by manually cutting in and out the necessary number of burners.

Symbols

FRCa = flow recording controller;
LRCa = level recording controller;
PRCa = pressure recording controller;
TRC = temperature recording controller;
PCVb = pressure control valve with balanced diaphragm;
PI = pressure indicator;
PC = pressure controller;
TI = temperature indicator;
FICa = flow indicating controller; and
Suffix 'a' = pneumatic transmission.

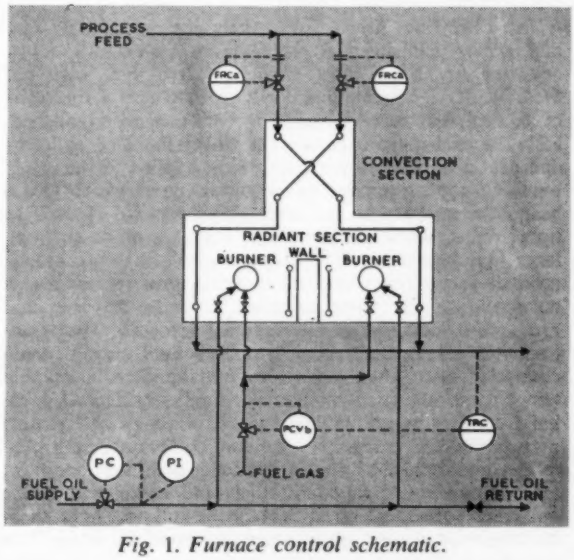

Fig. 1. Furnace control schematic.

Mr. Hill *is with Kellogg International Corporation.*

* Abstract of a paper read before the Society of Instrument Technology, Tees-side section, on November 14, 1957.

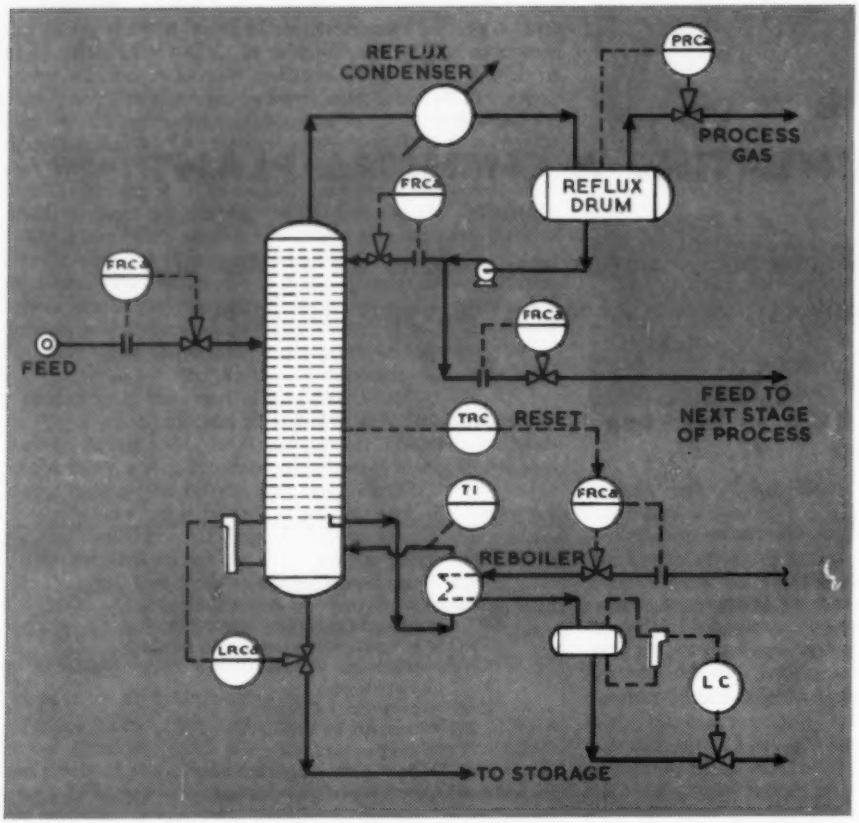

Fig. 2. Schematic diagram of the instrumentation for the control of a fractionating column.

Distillation Column Control

The control of fractionating columns is probably one of the most controversial problems in instrument control, and one on which most engineers have their own pet theories. It is extremely difficult to standardise on types of control, but certain basic concepts can be established. Fig. 2 shows a typical tower in which the feed is introduced at a suitable tray, reboiler heat applied to the tower base and cooling applied to the tower overheads to give a heat balance. Part of the condensed overhead is used as tower reflux, whilst the remainder is drawn off as an overhead liquid product. The diagram also shows a gaseous product taken from the reflux drum, and, of course, a bottoms product. These so-called products may be final products to storage, or alternatively feeds to other fractionating columns, furnaces, etc. Reboiler heating media consist of steam, hot vapours or hot liquids at a suitable temperature above tower bottoms temperature, and overhead cooling is normally by water, although refrigerants may be necessary for low-temperature separation.

The main variables in a fractionating column are flow, temperature, pressure, composition and levels in the base and reflux drum. The control problem is to hold these variables as steady as possible in order to attain "on specification" products, whilst at the same time accepting that some of the variables such as feed composition may vary due to conditions external to the fractionating column. Thus, if possible, the feed to the tower should be on flow control to maintain a steady flow through the column, with occasional changes to set point being made by the operator to cover changes of plant throughput, and to correct for excessive changes in inventories in vessels either feeding the column or receiving material from the column.

If lines from the tower base or reflux drum are routed to product storage tanks then they should be on level control to hold levels at the tower base or reflux drum steady. If, on the other hand, the lines are feeds to other fractionating columns or furnaces, then they should be on flow control with a level pen on the same chart. This will permit the level to vary between fairly liberal limits, thus taking up the surge in the system, whilst at the same time providing a steady feed to the next stage of the process. Variation in inventory level is one of the best ways of taking up the slack in a process unit, since it has little or no effect on material composition. If it is anticipated that the holding capacity of tower base or reflux drum will not be great enough to take up system surges, so that there is a danger of losing pump suction, then the draw-off lines may be on level control resetting the flow controller. However, even with this cascade system the level controller should be set with a wide proportional band

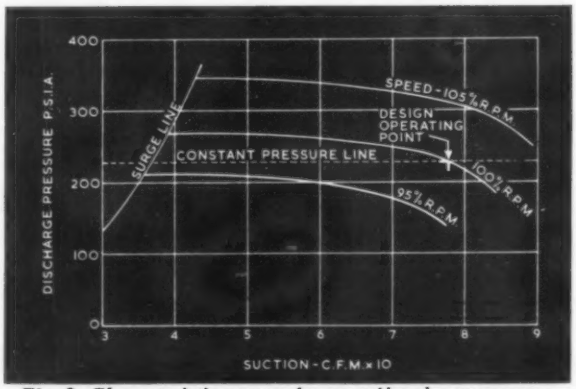

Fig. 3. Characteristic curves for centrifugal compressors.

and little or no reset, so that violent changes in flow do not occur, and the level is allowed to swing between controlled limits.

Centrifugal Compressor Control

The normal control for a centrifugal compressor is based on the characteristic curves of differential pressure against capacity for various operating speeds, as for a centrifugal pump. If the compressor is driven by a constant-speed motor, it is normal to vary the capacity by providing a vane-type control valve in the suction line to the compressor, rather than by a valve in the discharge side. With this arrangement, a small pressure drop across the vanes gives an appreciable change in the pressure ratio between discharge and suction. This results in a saving of motor horse-power.

If the compressor is turbine driven, the capacity is controlled by variation of the speed. Fig. 3 shows a typical family of pressure ratio versus capacity curves for various operating speeds. The compressor is normally operated at a constant pressure ratio to hold the suction and discharge systems at a constant pressure. By moving along the constant pressure ratio line of the curves, therefore, it will be seen that a variation in capacity can be provided by varying the compressor speed.

At low capacities the operation of the compressor becomes unstable and the machine starts to surge, giving large variations and even reversals of flow, accompanied usually by extremely noisy operation. Opinions differ as to the danger of operating under surging conditions, but it is a state of affairs which should normally be avoided. The compressor manufacturer will indicate the surge line on the characteristic curves which will show the minimum operating capacity for various operating speeds. The process control should then be arranged so that the machine is at all times kept above the surge point.

Fig. 4 shows such a control system. The compressor is turbine driven, and a pressure controller connected to the suction drum actuates the turbine throttle valve, with the governor holding the turbine at the speed corresponding

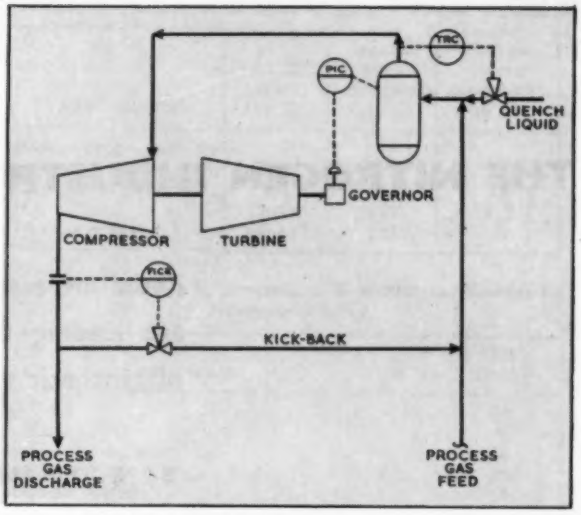

Fig. 4. Centrifugal compressor control.

to the output signal from the pressure controller. Thus, if the pressure in the suction drum falls, the throttle valve closes, causing a decrease in speed and capacity. If the capacity drops to a value close to the surge point, as given by the set point of the flow controller in the compressor discharge, then this flow controller begins to open the kick-back valve to maintain a minimum flow through the compressor.

Conclusion

The above account covers some aspects given in the paper of process unit control and indicates the problems which face the chemical plant contractor. In solving these problems, a critical assessment must be made of established practices and new techniques, so that a correct balance is maintained between capital cost and plant performance.

Partington's £2-million Gas Plant

Will have a capacity of 7,500,000 cu. ft of gas a day

PLANT costing £2 million which will produce town gas by the hydrogenation of coal or oil is to be built at Partington, near Manchester, by the North Western Gas Board. The installation will have a capacity of 7,500,000 cu. ft of gas a day, and it is being regarded as a full-scale demonstration unit to prove the efficiency and economics of the new process. The process will comprise the production and purification of hydrogen by the gasification of oil (and at a later stage coal) and the use of this hydrogen for hydrogenating further oil or coal to yield a rich gas which will then be diluted.

The hydrogenation section, the key to the process, was elaborated to the pilot stage by Dr. F. J. Dent, director of the Gas Council's Research Station at Solihull. The Texaco Development Corporation's hydrogen-producing process will be used. The crude gas will be passed to the carbon monoxide conversion plant, and after the carbon dioxide and hydrogen sulphide in the gases leaving the converters have been removed by absorption in potassium carbonate solution by the Benfield process, the hydrogen, then at least 90% pure, will be fed preheated into the hydrogenator together with preheated oil. The product of hydrogenation is mainly methane with a proportion of ethane. Aromatic compounds will be removed by condensation and scrubbing with circulating oil, and the resultant gas of about 600 Btu cu. ft calorific value diluted with nitrogen to the required calorific value, and density. In this first installation the carbon monoxide content will rise no higher than 1.5%. Other advantages claimed for the new method include freedom from sulphur compounds and availability of the gas at high pressure; moreover, a wide variety of oils can be used with it, and later it is intended that low-grade coal will take the place of oil.

Gas made in the demonstration plant, it is expected, will cost roughly the same as that produced by conventional methods, but for bigger plants considerable reductions in both capital and operating expenditure would result. It will operate by a sequence of continuous automatically-controlled processes, which have been designed by its builders, Humphreys & Glasgow, Ltd. (who are licensees of the Texaco and Benfield processes), in collaboration with the development department of the North Western Gas Board.

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THE NITROGEN INDUSTRY OF THE U.S.S.R.

Rapid increases in demands for fertilisers in the U.S.S.R. are leading to major developments in the production of synthetic ammonia, nitric acid and nitrogen fertilisers

By E. Y. MELNIKOV

THE first nitrogen plant in Russia was designed by engineer Andreyev and built in 1917 in the town of Yuzovka (now Stalino) in the Donbas. For that time it was a first-class chemical enterprise with Russian-made equipment, one of the biggest of its kind, the rated capacity being about 10,000 tons* of weak nitric acid a year, produced from a by-product ammonia liquor and worked up into ammonium nitrate.

The rapid transformation of the Soviet Union in the 1930s from an agrarian into an industrial country entailed rapid development of the chemical industry and notably the nitrogen industry. Although nitrogen products were in great demand by industry, development of the nitrogen industry was a vital necessity particularly for agriculture, which was in acute need of nitrogen fertilisers. In that period the Berezniki, Stalinogorsk (Bobriki) and Gorlovka nitrogen fertiliser plants went into operation and the nitrogen plant in Dzerzhinsk was considerably enlarged.

By the middle of the 1930s, the country's engineering industry was already able to turn out all the modern chemical apparatus, machines and instruments needed for the nitrogen fertiliser plants. The necessary conditions were thus created for the further growth of this branch of industry and in the second half of the 1930s a number of large new nitrogen fertiliser plants were built and those launched previously were improved and enlarged.

The Second World War caused a large amount of damage to the country's nitrogen industry, retarding its development. In the twelve post-war years the nitrogen industry not only healed the serious wounds it received but continued to grow, until today it has become a powerful branch of the chemical industry.

The increase in output of mineral and nitrogen fertilisers over the period 1940 to 1955 is shown in Table 1. Here, output of nitrogen fertilisers is given in terms of ammonium sulphate.

To improve crop yields further, the mineral fertiliser industry (including the nitrogen industry) was given the assignment of producing 11,600,000 tons last year (1957) and stepping up output to 19,600,000 tons in 1960. Measures mapped out to ensure such a considerable growth in production include the construction of new plants and the enlargement and reconstruction of existing ones.

TABLE 1.—Output of Nitrogen Fertiliser in Terms of Ammonium Sulphate

Type of Fertiliser	Total output (in thousands of tons)			
	1940*	1945	1950	1955
Mineral	3237.6	1119.1	5492.4	9640
Nitrogen	972	744.7	1908.3	2984

* *The year before the war.*

TABLE 2.—Comparison of Gas Compositions

Gas	Composition of the semi-water gas in vol. %					
	H_2	CO	N_2	CO_2	CH_4	H_2S
Gas after periodic gasification ...	36—38	34—36	20—23	6—7	0.2—0.3	0.3
Gas after continuous gasification of brown coal ...	29—30	31.5—33.5	20—20.5	16—17	0.3—0.4	0.8—1.2

The characteristic features of both new and enlarged plants are:

(a) use of cheaper types of raw material—in particular, natural gas tapped while extracting oil, coke-oven gas, and oil-well and refinery gases;

(b) large-scale combination of nitrogen industry production processes with the synthesis of organic compounds, such as alcohols, aldehydes, amines, resins for artificial fibres and plastics, and semi-manufactured products for synthetic rubber; during the past few years petrochemistry has been extensively combined with the nitrogen industry. Thus, carbon monoxide and hydrogen are used not only for the production of ammonia but also for the output of methyl, isobutyl and other alcohols. Ethylene and propylene obtained in the production of ammonia by the separation of coke-oven gas are correspondingly transformed into ethylbenzol and isopropylbenzol. Thermo-oxidation pyrolysis of methane gives acetylene, hence acetic acid and its derivatives, while the synthesis gas can be used for the production of ammonia. Out of the product of oil-refining-propylene with the combination of carbon monoxide and

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* All quantities given in this article are in metric tons.

hydrogen we can get butyl and isobutyl alcohols by means of oxosynthesis.

(c) large capacity and advanced technological processes incorporating large, highly productive aggregates and machines with individual aggregate capacity ratings, as a rule, of 50,000 to 75,000 tons of ammonia a year; and

(d) all-round automation of departments.

Plants in operation which do not lend themselves readily to considerable enlargement are being reconstructed. Here obsolete equipment is replaced by more improved and efficient equipment and additional means of automation are introduced.

All this will make it possible substantially to reduce initial capital investments, curtail operating and maintenance personnel and lower production costs.

Production of Synthetic Ammonia

To date, the most important sources of raw material for the production of synthetic ammonia in the Soviet Union have been coke, coke-oven gas and brown coal. Both intermittent and continuous coke gasification processes are extensively employed to produce the hydrogen-nitrogen gas mixture. Gasification of the finer fraction of coke (8 to 20 mm) in a continuous producer-gas generator with an air-oxygen steam blast is more profitable than gasification of metallurgical coke, which is in short supply.

With the great diversity of raw material in a country the size of the U.S.S.R., continuous gasification of brown coal has likewise become widespread. At present the methane content of gas obtained by this method only slightly exceeds that of gas obtained by the gasification of coke. This is seen from Table 2.[5] Perfection of the gasification process has also made it possible to cut down sharply the carbon dioxide content of water gas and semi-water gas and to curtail the consumption of oxygen per ton of ammonia. This was achieved by raising the temperature of brown coal gasification and simultaneously cooling the upper part of the generator, which has eliminated the adhesion of ash in the upper part of the generator.

The U.S.S.R. also has big reserves of peat—more than 60% of world resources. Peat is of considerable interest as a raw material source for certain parts of the country. Experimental work on continuous gasification of peat has shown that it can be successfully employed to produce ammonia.

TABLE 3.—Indices of Relative Costs per Ton of Ammonia

Raw material	Production costs (in %)	Specific capital investments (in %)	Specific labour expenditures (in %)
Coke-oven gas by low-temperature separation ...	100	100	100
Coke	120-150	110	125
Brown coal	140-175	125	130

TABLE 4.—Change in Structure of Raw Material Sources for Nitrogen Industry

Raw material	1956 (in %)	1960 (in %)
Coke	40	16
Coal	5	8
Coke-oven gas	34	34
Natural gas	21	29
Other sources		13
Total	100	100

Coke-oven gas is processed into the hydrogen-nitrogen mixture both by separation at low temperatures and by reforming methane, the residual unsaturated hydrocarbons being employed for organic synthesis.

An oxygen-steam catalytic method of reforming methane was devised and studied in detail back in 1931 to 1934 by the Nitrogen Institute in Moscow. Later other methods of reforming methane were investigated and tested by the same institute[2-4]—in particular a method called explosive conversion, based on the incomplete oxidation of methane by oxygen in the cylinder of a gas engine or in the chamber of a gas turbine with the production of energy. Pilot-plant tests of this method were made back in 1940, and tests on a large scale in 1952. Thus, under oxygen-steam conversion of natural gas containing CH_4—97.6% (in volume percentage), C_2H_6—0.3%, C_3H_8—0.1%, N_2—1.5%, CO_2—0.5%, gas of the following composition may be obtained: H_2—72.1%, CO—3.8%, CO_2—23%, CH_4—0.4%, N_2—0.7%.[6]

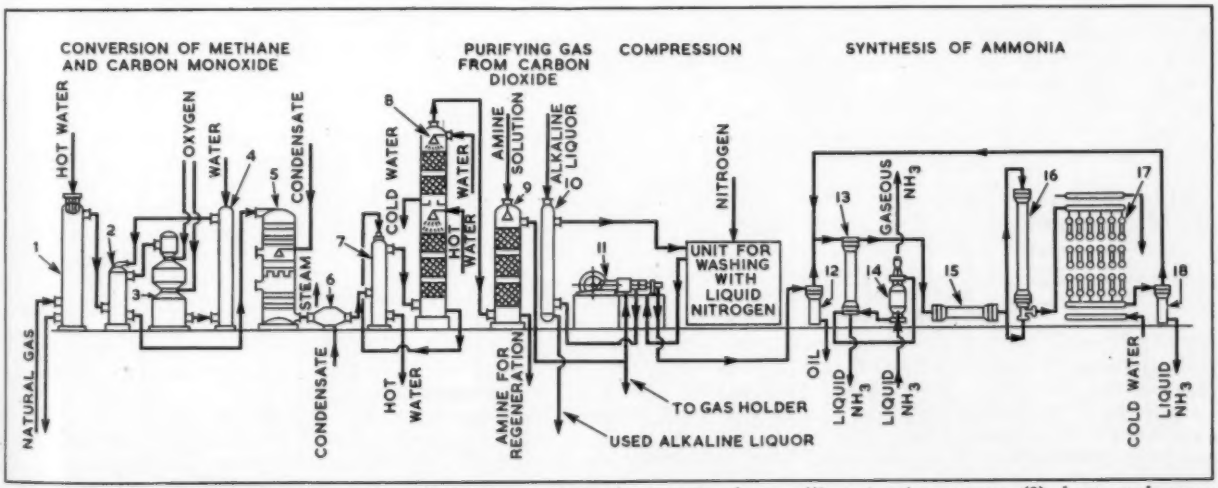

Fig. 1. Fundamental scheme for obtaining ammonia from natural gas. (1) *saturation tower;* (2) *heat exchanger;* (3) *methane converter;* (4) *moistener;* (5) *carbon monoxide converter;* (6) *boiler;* (7) *water heat exchanger;* (8) *water heater and condensation tower;* (9) *absorber;* (10) *alkaline scrubber;* (11) *compressor;* (12) *filter;* (13) *condensation column;* (14) *ammonia condenser;* (15) *turbocirculary pump;* (16) *ammonia synthesis column;* (17) *water condenser;* (18) *liquid ammonia separator.*

In a 300-hp gas engine working with enriched air that contains 72% oxygen, a gas of the following composition was subjected to "explosive" conversion: CH_4—53.5%, C_2H_4—3.2%, H_2—5.4%, CO—11.2%, N_2—26.7%. As a result of "explosive" conversion, a gas of the following composition was produced: H_2—41.9%, CO—31.3%, CO_2—3.4%, CH_4—0.4%, N_2—22.5%, O_2—0.5%.[7] If this gas is subjected to CO conversion its composition will be as follows: H_2—54.0%, CO—3.5%, CO_2—24.2%, CH_4—0.3%, N_2—18.0%.

Both in the first and the second case the resulting gases can be used for further working into ammonia.

Plants using coke-oven gas to work up into synthetic ammonia give the cheapest products. Production of the hydrogen-nitrogen mixture from coke-oven gas is likewise characterised by smaller specific capital investments and expenditures of labour.

Indices of the production costs, capital investments and labour expenditures per ton of ammonia are given in Table 3, the indices for coke-oven gas being taken as 100%.

The discovery of big natural-gas deposits in the North Caucasus, the area of the middle reaches of the Volga, the Trans-Volga area, the Northern Urals and a number of other localities, and the rapid layout of a ramified network of gas pipe-lines in the country will lead to natural gas becoming in the near future a highly important raw material source for the nitrogen industry. As a source of raw material for the manufacture of ammonia, natural gas approaches coke-oven gas in production costs, specific capital investments and specific labour expenditures. Therefore, with a view to cutting production costs, we have already begun to switch over several nitrogen fertiliser plants from coke to natural gas. It has been calculated that the additional capital investments involved will repay themselves in a little over a year. In the very near future the cheapest sources of raw material—coke-oven and natural gases—will be drawn on to make the bulk of the ammonia in the U.S.S.R. At present, however, most of the ammonia is made by gasification of coke, with coke-oven gas as the second most important source of raw material.

The change in structure of the raw material sources of the country's nitrogen industry is shown in Table 4.[8]

In addition to natural gas, it is also intended to use the oil-well gas obtained while extracting oil and the gases produced by petrochemical plants. These gases may be processed into ammonia by several methods, the choice depending upon the specific conditions of each individual plant.

Of great interest, in my opinion, is the possibility of combining ammonia production with the manufacture of acetylene from methane gases, say by the thermo-oxidation method. Here, following the separation of acetylene and other admixtures, residual gases can be processed into the hydrogen-nitrogen mixture that goes to synthesise ammonia. The gases obtained by means of thermo-oxidation pyrolysis of natural gas have the following composition (in volume percentage): CO_2—3.5-4%; C_2H_2—8.2-8.6%; C_2H_4—0.6%; O_2—0.2%; CO—26-28%; H_2—50-53%; CH_4—4.5-6%; N_2—0.8-1.5%. After the separation of acetylene the composition of the gas will be as follows: CO_2—3.9-4.4%; C_2H_2—0.1%; C_2H_2—0.6%; O_2—0.2%; CO—28.5-30.5%; H_2—55-58%; CH_4—5-6.5%; N_2—0.9-1.6%.[9]

It is also expedient to combine ammonia production with low-temperature oxidation of the hydrocarbons of oil-well gases to form aldehydes and methanol. Here, too, following the separation of the low-temperature oxidation products, the residual gases can be processed into the hydrogen-nitrogen mixture.

While building new plants, several technical problems arose that are now being successfully solved. For instance, in a number of cases it is expedient to utilise the available

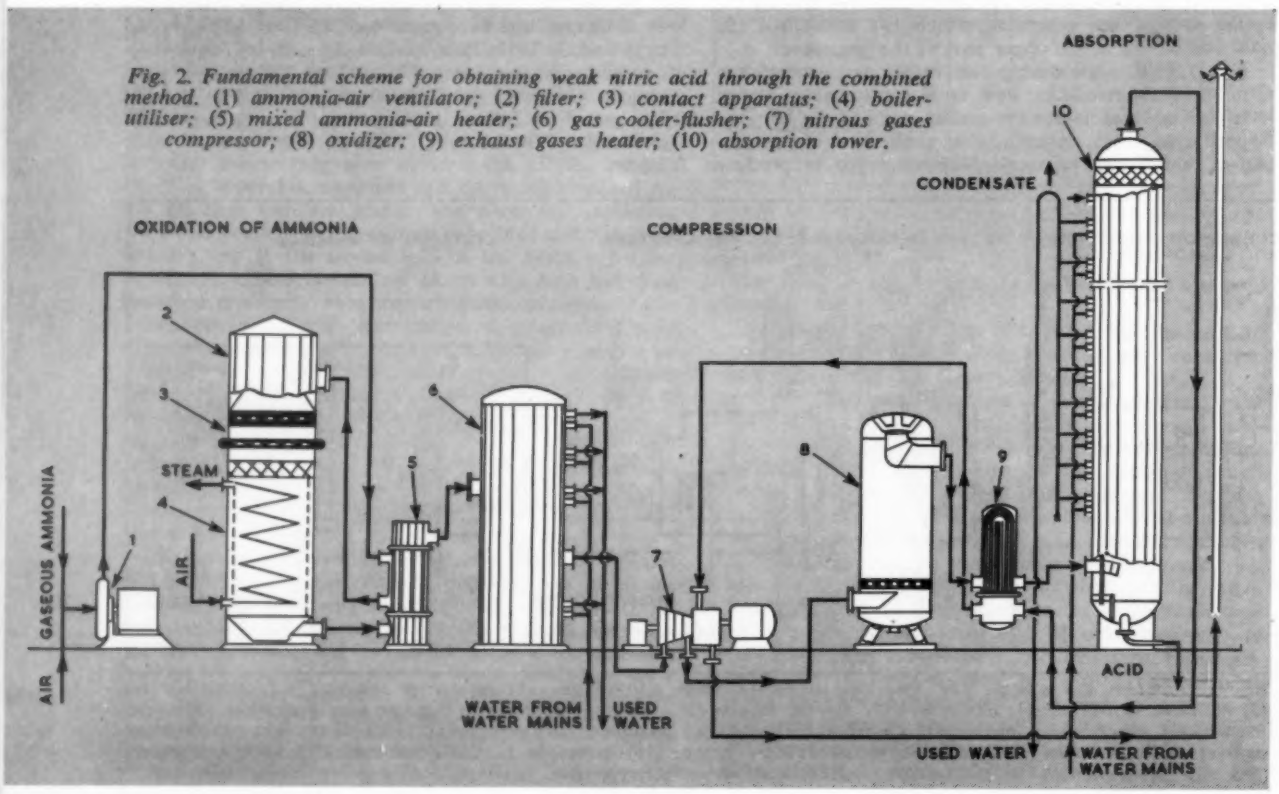

Fig. 2. Fundamental scheme for obtaining weak nitric acid through the combined method. (1) *ammonia-air ventilator;* (2) *filter;* (3) *contact apparatus;* (4) *boiler-utiliser;* (5) *mixed ammonia-air heater;* (6) *gas cooler-flusher;* (7) *nitrous gases compressor;* (8) *oxidizer;* (9) *exhaust gases heater;* (10) *absorption tower.*

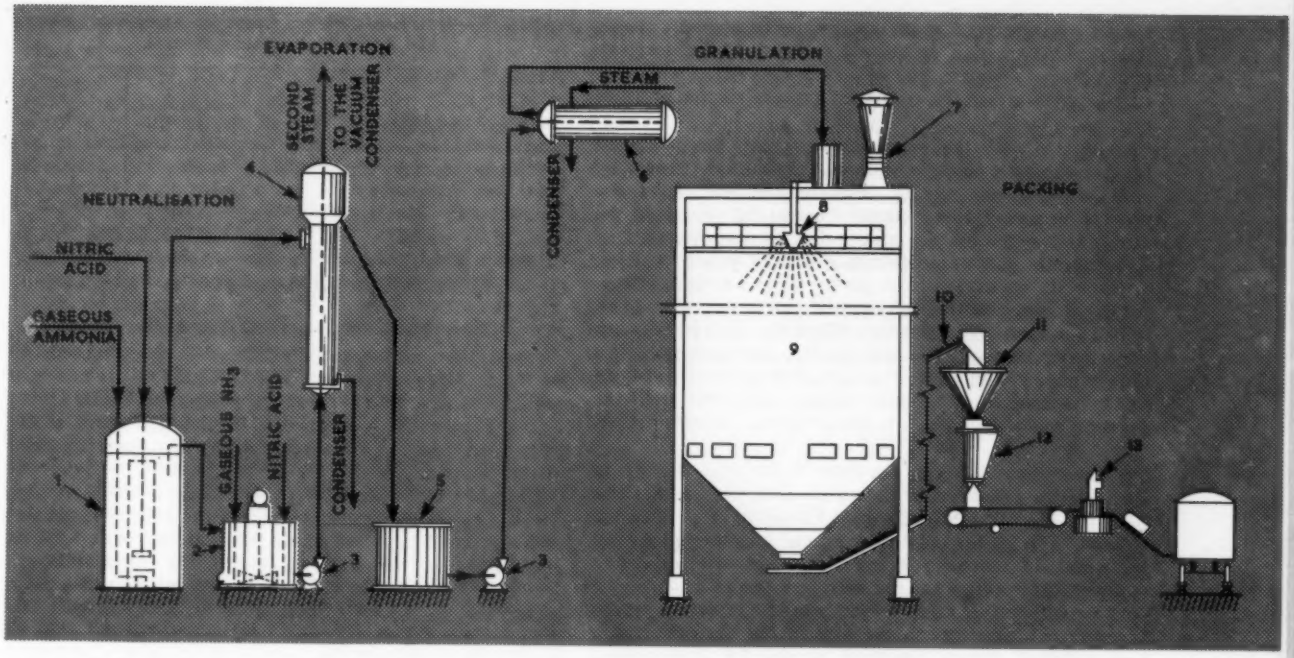

Fig. 3. Production of granulated ammonia saltpetre. (1) *neutraliser;* (2) *deneutraliser;* (3) *centrifugal pump;* (4) *evaporation apparatus, first stage;* (5) *tank hydraulic seal;* (6) *evaporation apparatus, second stage;* (7) *ventilator;* (8) *granulator;* (9) *granulation tower;* (10) *transporter;* (11) *bunker;* (12) *scales;* (13) *binding machine.*

initial pressure of the natural gas to process the latter into the hydrogen-nitrogen mixture under pressure. This makes it possible to cut down power expenditure to compress the gases, and also to curtail the overall dimensions of the equipment.

When coke-oven gas or the gases obtained in the gasification of brown coal are used as raw material sources, elimination of hydrogen sulphide from them becomes a serious problem. At present Soviet industry employs both dry and wet methods of purification. The dry methods of purifying semi-water gas, in particular the one employing activated charcoal, are cumbersome. The wet methods also have a number of shortcomings. Purification by means of sodium thioarsenate solution, for instance, is a satisfactory method for cleaning practically any industrial gas irrespective of the initial hydrogen-sulphide concentration, but it is a technologically complicated process requiring a large quantity of labour power. If the purifying agents chosen are amines, which are suitable for elimination of hydrogen sulphide from many industrial gases, it is easy to automate the process, but greater expenditure of steam is required. Furthermore, when employing this method, the gases containing hydrogen sulphide should also be used for sulphur or sulphuric acid production. Therefore, the problem of devising a more improved method of eliminating hydrogen sulphide is so far unsolved.

At big plants turbo-compressors are used to bring the gas to medium pressures. Installation of high-efficiency compressors makes it possible to curtail their number, cut down repairs and reduce the size of the shops.

The wide use of oxygen in processing methane gases, brown coal and coke has created the prerequisite for using in plants now under construction, nitrogen, produced during air separation. Liquid nitrogen can be added to reformed gas, yielding purer hydrogen-nitrogen mixtures.

Ammonia synthesis sections now in use operate under a pressure of 300 to 600 atmospheres. It should be noted that high-pressure systems play a very small role in the overall production of ammonia, accounting for less than 10% of the total output. All the rest is produced by medium-pressure systems. The new plants going up will also have ammonia synthesis sections operating under medium pressure. The terms "high pressure" and "medium pressure" refer to the ranges 500-800 atmospheres and 250-820 atmospheres respectively.

The previously-installed ammonia synthesis units with a 24-hour output of 60 to 100 tons are not productive enough for big plants. Units are now being designed with a 24-hour capacity of 200 tons of ammonia and an average catalyst efficiency of 40 tons a cu. m every 24 hours, the process proceeding at space velocities of the order of 20,000 to 25,000 $hr.^{-1}$

With a view to simplifying the ammonia synthesis process and cutting down contamination by oil vapours, turbo-circulating pumps will be employed to circulate the hydrogen-nitrogen mixture in the units. To make the process more economical some plants utilise a considerable part of the heat of reaction; for instance, to heat up the condensate feeding the power plant boilers. Processes are now being developed to put the heat of reaction to more general use.

It is of interest that over a period of 15 years methanol has also been manufactured in the U.S.S.R. with equipment designed for the synthesis of ammonia. This allows for more flexible utilisation of equipment.

Production of Weak Nitric Acid

The distinguishing feature about nitric acid production in the Soviet Union is the great variety of processes employed. As well as systems based on oxidation of ammonia at roughly normal pressure and absorption of the oxides, there are a number of installations in operation where the oxidation and absorption is done under a pressure of 5 to 8 atmospheres absolute, and also systems employing oxidation at atmospheric pressure with absorption under a pressure of 3.5 to 7 atmospheres absolute.

The sections operating under pressure account for 40% of the acid produced. Only an insignificant quantity of

acid is manufactured at present by the combined process, that is, by oxidation at normal pressure and absorption under higher pressure. The new plants going up will, as a rule, employ either the combined process or the pressure process.

Compared with the pressureless process, the combined process makes it possible to curtail capital investments by 25%, since it considerably decreases the volume of the absorption system. For example, whereas the volume of the absorption system in the pressureless process amounts to 27 m^3/ton of the monohydrate every 24 hours, when a pressure of about 3.5 to 4 atmospheres absolute is employed in the absorption system, its volume amounts to only 2.1 m^3/ton every 24 hours. When the absorption is not done under pressure, it is usually necessary to supplement the equipment with an alkaline absorber to fix the nitrogen oxides in sodium or calcium nitrites and nitrates. In the pressure process, alkaline absorption of the nitrogen oxides is not required.

Pressure has not been the only factor contributing to such a large reduction in absorption volume; another has been the use of highly effective absorption devices in the column. The plates employed in the absorption column are simple in construction and make it possible to ensure complete absorption of the nitrogen oxides in a single column without resorting to the use of circulating pumps for the acid. The loss in pressure in the absorption and heat-exchange system does not exceed 0.5 atmospheres, which makes it possible to increase the degree of recuperation of energy of the compressed gas in the turbine.

Although in the combined and the pressureless processes less platinum and ammonia are consumed than in the pressure process, specialists are now again turning their attention to the latter process, since in big-capacity plants the ammonia oxidation section becomes very cumbersome, and it is undesirable to employ turbo-compressors for nitrous gases owing to their high cost and more involved maintenance.

Efforts are therefore now being made to improve the pressure process. The trend is, in the first place, to achieve a degree of conversion of ammonia into nitrogen oxides approximately equal to that produced by pressureless oxidation, and, in the second place, to reduce consumption of platinum considerably.

To achieve high and stable conversion coefficients, the trend of research at present is to improve purification of the air used to oxidise the ammonia and also to improve purification of the ammonia. This research is of especial interest for large chemical plants, since the air around the plant is frequently very contaminated.

A number of fundamental improvements have been introduced in pressureless ammonia oxidation processes over the past few years. For instance, for several years now one large plant has been using a two-stage catalyst that employs platinum only during one stage. This cuts down initial investments in platinum and curtails its specific consumption without decreasing the degree of conversion of ammonia into nitrogen oxides. There is also in operation a large unit that employs a non-platinum catalyst,[10] which eliminates platinum entirely from the process. Furthermore, more rational use has been made of the heat of reaction by employing economisers and installing boilers giving high-pressure steam. In the latter case the steam is first used for power generation, giving about 60 kWh of electrical energy a ton of acid, and then for process heating; it may be fed, for example, to the evaporators in the ammonium nitrate department.

Several plants processing coke-oven gas into the hydrogen-nitrogen mixture by employing air separation units contain excess oxygen. The latter is used in the production of weak nitric acid, intensifying the absorption-oxidation system and cutting down expenditure of energy on air compression in systems operating under pressure.

TABLE 5.—Indices of Relative Costs for Ammonium Nitrate and Calcium-ammonium Nitrate

Type of Fertiliser	Production cost (in %)	Capital investments (in %)	Labour expenditure (in %)
Ammonium nitrate ...	100	100	100
Calcium - ammonium nitrate	115-120	125	140-150

Production of Nitrogen Fertilisers

Ammonium nitrate is the principal fertiliser turned out by the nitrogen industry of the U.S.S.R. and it has now headed the list for more than 20 years. The Soviet Union was a pioneer of its large-scale use in agriculture in the pure form, and for many years it has also been produced in the form of granules for this purpose.

Research aimed at cutting down caking during storage has resulted in the development of several types of nitrates with inorganic admixtures that are practically non-caking and are now being manufactured by most nitrogen fertiliser plants in the U.S.S.R. A non-caking ammonium nitrate can be made by adding 0.5% CaO + MgO. The granules were between 1.5-2.5 mm in size.[11] Many years of experience in their application in agriculture has confirmed that they are practically non-caking when stored not only in good warehouse conditions but also in poorer conditions at the point of consumption. They retain their free-running properties both after production and when introduced in the soil. Very rarely is there any recrystallisation and destruction of granules during storage and even then only to an insignificant extent.

Low production costs, high concentration of fixed nitrogen, good agro-technical qualities and the virtual freedom from caking have retained for ammonium nitrate to this day the dominating place it has occupied among the nitrogen fertilisers.

Sodium and calcium nitrates are being manufactured at a number of plants. Sodium nitrate is made in the Soviet Union by one method only: by processing the nitrite-nitrate solutions formed during the alkaline absorption of the nitrogen oxides left after acid absorption. This method is similarly used to produce calcium nitrate, part of which is also obtained by nitric acid decomposition of phosphates.

Calcium nitrate is not produced in Russia by the neutralisation of nitric acid owing to the relatively high cost of the nitrogen in the resulting product. Sodium and calcium nitrates play a comparatively small role as nitrogen fertilisers.

Ammonium sulphate and ammonium sulphate-nitrate have not been produced by plants of the nitrogen industry for more than 15 years, since they are relatively expensive, have low concentrations of nitrogen and poorer agrochemical properties than ammonium nitrate. The coking industry, however, continues to turn out ammonium sulphate, and it is also obtained as a by-product in the manufacture of caprolactam.

Calcium-ammonium nitrate is not manufactured at all in the Soviet Union because the production costs, capital investments and expenditure of labour involved considerably exceeded those for ammonium nitrate, which can be seen in Table 5.

When calcium ammonium nitrate is employed, much more also has to be spent on containers, transport, storage and introduction of the fertiliser into the soil. It is cheaper to introduce ammonium nitrate and lime into sour soils than calcium-ammonium nitrate.[12]

Synthetic urea, which began to be produced in the country more than two decades ago, goes in the main for industrial purposes and only partly for the needs of agriculture. This is explained by the fact that the cost of a unit of fixed nitrogen in it has been appreciably higher than in ammonium nitrate. However, the next few years will see the construction of a number of big capacity plants producing synthetic urea, which will noticeably boost output, with most of the product going for fertiliser and fodder. Moreover, the cost of the nitrogen in it will approach that in ammonium nitrate.

Liquid fertilisers were tested on Soviet farm fields back in 1932 to 35 with good results. Lately, successful field experiments with liquid ammonia, ammonia solution and nitrogen solutions have been carried out in a number of districts of the Ukraine and Uzbekistan. They promise liquid fertilisers a prominent place in the country's nitrogen fertiliser arrangements within the next few years.

The nitrogen industry of the U.S.S.R. is also turning out complex fertilisers, a product of the nitric acid decomposition of apatite with subsequent treatment by ammonia and the addition of potassium chloride. However, so far output is relatively low, the large-scale production process still being in the development stage.

In 1960, at the end of the current five-year plan period, there will not only be a sharp increase in production of nitrogen fertilisers but also a marked change in their lines of output. A prominent place among them alongside ammonium nitrate will be taken by other concentrated fertilisers like urea, liquid fertilisers and complex fertilisers.

Characteristic of the nitrogen industry of the U.S.S.R. as a whole, which is advancing in line with the national-economic plan, is the high pace of development needed for the speediest satisfaction of the growing requirements of the national economy, the diversity of raw materials and the variety of methods employed for obtaining ammonia and processing it into concentrated nitrogen fertilisers. Another characteristic feature is the large-scale combination of the nitrogen industry with the heavy organic synthesis and petrochemistry industries. New and enlarged plants are being fitted out with highly efficient automatic equipment and existing ones are being modernised.

The U.S.S.R's nitrogen industry has well-trained production personnel and large staffs of skilled researchers and engineers, which is an indication that the tasks confronting it will be fulfilled.

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New Refinery Desulphurising Plant

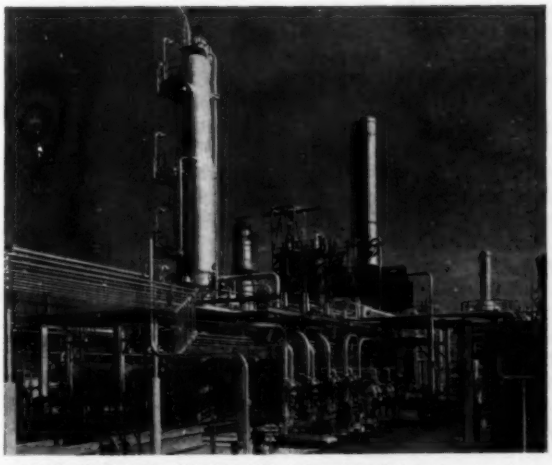
Unique Process in Use at Martigues, France

THE new desulphurising plant of the *Compagnie Française de Raffinage* at the *Raffineries de Provence* at Martigues, France, has just been put on stream. Designed and constructed by Kelloggs, it is intended to extract 85% of the sulphur content of 12,500 barrels a day of an 80/20 mixture of products from crude oil and a light oil from the catalytic recycling process. The catalytic reaction in the process utilises cobalt molybdate and the reaction conditions were elaborated in the laboratories and pilot plant of *Compagnie Française de Raffinage* and Kellogg's. Alternatively, the plant can treat naphtha from the first distillation and kerosene, and then a removal of 75% of the sulphur is attainable.

Certain sections of the plant have a greater capacity than the plant as a whole, and can handle, for example, 10,000 barrels a day naphtha from the first distillation, and 7000 barrels a day of kerosene. This allows a balance to be struck between the needs for a high degree of desulphurisation and a product of satisfactory colour. To aid in the flexibility of the plant, two reactors have been installed, and the calculated space velocity for the treatment of gas oil can be maintained while the unit functions at half of its capacity. The following figures provide an idea of the capacity of the plant:

Capacity of Plant

	Gas-oil	*Kerosene*	*Naphtha*
Non-treated charge barrels a day	12,500	7000	10,000
Desulphurised products, barrels a day	11,900	6976	10,007



C.F.R.'s Catalytic Desulphurising Unit. Left to right: Stripper tower reactors, feed and recycle gas furnace, and regeneration heater

A process said to be unique is used for separating the products of the reactor. This includes a progressive expansion and absorption of the lighter fractions of the recycle process which allows a high percentage of hydrogen to be present in the gas stream recycling from the reactor. Moreover, the fact of sending the combined liquids to the stripper results in economy in the quantity of heat used and in the size of the heat exchanger. The heat saved is employed for raising the temperature of the charge of oil.

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REFRACTORY CORROSION AND GLASS FLOW

New approaches to glass-making problems

Two ATB11 blocks situated side by side in a glass-melting furnace. L.H.S. block porosity 20.4%; R.H.S. porosity 8.9%.

CORROSION in glass-making furnaces, the use of isotopes in the study of sand mixing and glass flow and the potentialities and limitations of instrumentation in glass-making were among the technical problems discussed at the first of a new series of general meetings at the Society of Glass Technology held recently in Sheffield (see *British Chemical Engineering*, January, 1958, page 3). A summary of some of the papers presented is published below.

Porosity and Corrosion Resistance

That the porosity of a glass-furnace refractory exerted a "first-order" influence on the material's corrosion in use was shown by Mr. T. S. BUSBY in a report of his recent work at the G.E.C. Laboratories, Wembley. Provided care was taken, he had concluded, refractories of low porosity could be used substantially to increase a furnace's life.

Although it had been agreed in the industry that a relationship existed between the porosity of a refractory and its corrosion by glasses or slags, since the porous material would offer a greater surface area for attack, few actual measurements had been published, he said. In his investigations samples of ATB11 mullite blocks with porosities of 1.8 to 20.6% were placed in four furnaces melting soda lime and borosilicate glass. When the furnaces were shut-down for repair the depth of corrosion of the blocks at the glass surface was measured and then plotted against the porosity of the block. With each furnace, which ran for periods of up to two years, there appeared to be a linear relationship between the depth of corrosion and the porosity of a block. Further, it was found that blocks standing side by side in the furnace showed considerable differences in the amount of attack (see illustration). These results were plotted statistically and it was found that three of the furnaces could be grouped together, but that the results from the other had a different value. In general, however, it could be said that by reducing the porosity from 20 to 10% the amount of corrosion was halved.

Samples of the same materials were also subjected to a static laboratory test in which fingers of the refractory were suspended in molten glass in platinum crucibles. Even under these static conditions there appeared to be a linear relationship between porosity and corrosion in the range 1 to 20% porosity and that the amount of corrosion could be substantially reduced by reducing the porosity.

Whilst blocks of very low porosity had desirable corrosion-resisting properties, they required more care in their use, since the dense materials were likely to fail due to thermal shock. However, if care were taken to heat the blocks uniformly and the temperature gradients were kept to a minimum by the use of insulation wherever possible, the problem could be overcome.

Tracer Study of Sand Mixing

A radioactive tracer method for studying the mixing of sand during treatment for glass manufacture was described in one of two papers read by Mr. R. S. BARKER (Pilkington Bros. Ltd., Sheffield). It was extremely sensitive and could be modified, the author said, for use in the study of throughput and mixing of many diverse materials.

In glass manufacture it was important that the sand used should be of uniform chemical composition, and it might be necessary to blend different batches to attain the target composition, Mr. Barker said. For that purpose, batches of sand were fed by hopper in turn into each of four vertical washers of about 25 tons capacity. Water was added and the slurry formed passed through sieves to remove stones and vegetable matter. The slurry was then piped through $\frac{1}{8}$-in. wall steel pipes to the grading plant, where the fine particles were rejected, and it was then allowed to flow into a drainage bin of 2000 tons capacity. After draining, the sand was removed for glass-making.

To determine the extent to which successive batches of sand were mixed together, it was necessary only to trace through the system a quantity of sand which had been introduced at a given time. The procedure adopted for labelling a quantity of sand was as follows:

100 millicuries of Ba 140 were adsorbed on to 10 lb. of washed and graded sand by immersion in a radioactive barium solution. The adsorbate was baked on to the sand at 500°C and tests showed that less than 5% of the total adsorbed activity was removed by violent agitation in water. (Ba 140, half life 12.8 days, decays by β emission into La 140, half-life 40 hours, which, in its decay to Ce 140, emits a 1.6-Mev γ photon, which can be readily detected through a thickness of $\frac{1}{4}$-in. steel.)

After allowing the lanthanum activity to grow into equilibrium, the activated sand was thoroughly mixed into 5 cwt. of inactive sand which was then fed into the washing plant. Measurement of the activity in the slurry flowing into and out of the grader were made by γ scintillation-counters mounted on the outside walls of the pipes carry-

ing the slurry and coupled to recording ratemeters. These measurements showed that the sand was well dispersed in the washing plant in that it took 17 minutes after the first appearance for 50% of the active sand to pass into the grader. 12 tons of sand had passed through the system in this period of time.

After sufficient time had been allowed for the sand to drain in the drainage bin, a survey of the activity in the bin was made with the use of a 6-ft-long probe carrying a Geiger counter and amplifier. These measurements showed further mixing of the sand in the bin. On removal from the bin, the sand was filled into railway wagons and readings of the activity of the sand in each wagon were obtained by a field ratemeter. By comparing these readings with those obtained in the bin survey, the mixing during removal from the bin could be estimated.

The batch made from the active sand gave a count-rate about four times greater than the background count. Measurements by a γ scintillation-counter were made of the activity of samples of glass produced during a three-week period after the first addition of active batch to the glass-melting furnace. Integration of the curve showing variation of count-rate with time gave a second curve showing the percentage of the total activity which had passed through the furnace at any instant. This curve also indicated the extent of mixing in the furnace and was very much nearer to the curve for complete mixing than that for displacement. This curve could also be used to predict the the effect of batch changes on glass composition at any time. For the particular furnace investigated, 180 hours would be needed before 50% of a batch change would become effective in the glass produced.

Radioactivation Analysis of Melting Processes

In his second paper Mr. Barker described a radioactivation analysis technique for the study of large-scale glass-melting processes. The method could be applied to studies of throughput, of the flow of glass to different parts of the furnace, and of glass composition.

Radioactive tracer methods appeared to be eminently suitable for studying the flow of batch through glass-melting furnaces, since they were highly sensitive and were unaffected by high temperatures, he said. Unfortunately, to investigate flow in large melting units, a high initial intensity of radioactivity of fairly long half-life would have to be added to the batch fed to the furnace. Thus the product would contain long-lived radioactivity which might be undesirable. To circumvent this difficulty, the technique of radioactivation analysis was adopted.

The 1350-ton capacity furnace investigated was producing a soda-lime-silica glass, and thus the non-radioactive tracer chosen had to contain a nuclide of high neutron excitation cross-section and which would yield on irradiation a γ-active isotope with a much longer half-life than those of the other radionuclides produced from other constituents in the glass. The substance best fulfilling these requirements was tantalum pentoxide which, on irradiation, yields tantalum 182.

The technique of using it was as follows: 3.75 kilo of tantalum pentoxide were mixed into 30 cwt. of batch and the mixture fed into the furnace. Samples of glass produced in the furnace were taken throughout a period of 22 days from the day preceding that on which the addition was made. A 5-G quantity of each sample was powdered and irradiated in the pile at Harwell in a flux of 1.2×10^{14} neutrons/cm.^{2}/sec. for one week. The samples were stored for five weeks to allow decay of the short-lived radionuclides before measurement was commenced.

The tantalum content of the samples could be estimated, it was explained, either by measurement of the total activity induced in the sample, or by counting only those γ rays with energy lying in a selected region of the spectrum. To reduce inaccuracies due to fluctuation of the background level by uncontrollable changes in the trace amount in the glass of elements of high excitation cross-section, the second method was adopted. A band-width was selected to include a peak of the γ spectrum of the Ta-182 containing glasses and one-minute counts taken for each sample. Throughout the counting procedure, care was taken to ensure constant geometry of the system.

From graphs showing the variation of count-rate with time of sampling, it was seen that tantalum started to appear in the glass in the working end of the furnace about four hours after it was added to the feeding end. The amount of tantalum (of the order of 2 parts per million) present in the samples increased until about 100 hours after the addition, and thereafter it decreased exponentially. From these graphs it was possible to draw a curve showing the amount of tantalum which had passed through the furnace at any instant of time. The curve, which might be used as a measure of the time delay before batch changes become effective, showed that there would be a delay of 200 hours before 50% of a batch change would become effective in the product.

Flow Studies using Radioactive Tracers

Mr. B. C. Moody (United Glass Bottle Manufacturers Ltd.) had used radioactive tracers to investigate glass flow in furnaces—a subject about which, he pointed out, there was much uncertainty.

None of the radioisotopes of the normal glass-making elements was of suitable half-life for the work, but provided that the amount of tracer needed was very small, its chemical identity was not important, he said. The half-life should be of the same order as the length of the experiment being carried out, and a pure beta-emitter was preferable to simplify handling and shielding. Phosphorus 32 (half-life 14 days) had been found suitable. The tracer was prepared in the form of a glass containing 51% of P_2O_5, which was then crushed and irradiated at Harwell to produce the required activity. The other constituents of the glass, potash and alumina, were of much shorter half-lives, and were allowed to decay sufficiently before the experiment. 90 gm. of this phosphate glass, of total activity 175 mc., was adequate for a furnace producing over 80 tons of glass per 24 hours.

The tracer was mixed with several pounds of the usual raw materials in a large glass jar fitted with a funnel, and placed in such a position over the furnace-feeding mechanism that a steady stream of labelled batch combined with the main flow of raw materials into the furnace. The feeding period was 30 minutes. The activity caused in the bottles produced was so low that they could be safely handled immediately without any risk or need for shielding. The use of a tracer in the form of a glass ensured that no significant volatilisation of the phosphorus occurred in the furnace.

The results, obtained by counting techniques on solid glass specimens, showed that for both colourless and amber glass, the minimum transit time through the furnaces was about six hours, and the peak concentration was obtained after about 24 hours. The concentration time curves obtained were used to estimate the age-distribution of the glass in the bottles, and also the age-distribution of the glass in the furnace. It was also possible to make some deductions about the mixing mechanism obtained in these furnaces. It appeared, for example, that the raw materials were subjected to an initial stage of displacement, followed by a stage of nearly perfect mixing.

A full report of the proceedings of the meeting will be published in the April issue of the *Journal of the Society of Glass Technology*. Copies may be obtained from the Society, at Thornton, Hallam Gate Road, Sheffield, 10, price 25s.

621.039.431

FISSION PRODUCT CONCENTRATION IN FLUID REACTOR FUELS WITH CONTINUOUS PROCESSING*

by A. M. ESHAYA†

An analysis of the concentration changes which occur in a given volume element of fuel as it passes through a continuous processing system

ONE of the advantages claimed for power reactors utilising fluid fuels is the possibility of continuously processing the fuel in a chemical plant which is an integral part of the reactor installation. In the usual case, this processing will involve removal of fission products from the fuel and addition of fissile material to make up for that consumed. Rapid adjustment of the concentrations of additives such as oxygen getters and corrosion inhibitors is also possible. This characteristic of fluid fuel reactors allows the realisation of operation conditions close to the design optimum. Control of the concentrations of fission product poisons within narrow limits results in a high neutron economy which is particularly important in the case of breeder reactors.

The mathematical relationships relating the concentrations of fission products to the rates of removal from the cycle have been derived by DWYER[1] on the basis of no change of concentration of any given nuclide as the fuel goes through the entire cycle; this is a valid assumption for practical reactor designs.

The present analysis takes into account the changes in concentration which occur in a given volume element of fuel as it proceeds through the cycle. The relationship between the removal rates of successive nuclides in a given chain is introduced as a parameter.

The following chain is considered:

$$A \longrightarrow B \longrightarrow C.$$

The modes of appearance and disappearance assumed for the three nuclides are listed in Table I.

TABLE I

Nuclide	*Modes of Appearance*	*Modes of Disappearance*
A	from fission of fuel $= \gamma_a \Sigma_f \varphi$	by decay to $B = \lambda_a A$ by neutron capture $= \sigma_a \varphi A$
B	from fission of fuel $= \gamma_B \Sigma_f \varphi$ from decay of $A = \lambda_a A$	by decay to $C = \lambda_B B$ by neutron capture $= \sigma B \varphi_B$
C	from decay of $B = \lambda_B B$	by neutron capture $= \sigma_c \varphi C$

Symbols

A = concentration of nuclide A in fuel in atoms/cc;
B = concentration of nuclide B in fuel in atoms/cc;
C = concentration of nuclide C in fuel in atoms/cc;
P = fraction of nuclide remaining in stream after processing;
Z = ratio of concentrations of nuclides at exit of processing plant;
t = time (sec);
γ = fission yield;
Σ = microscopic cross-section, cm^{-1};
φ = neutron flux, neutrons cm^{-2} sec^{-1};
λ = decay constant, sec^{-1}; and
σ = absorption cross-section, cm^2.

Subscripts

a, b, c, = pertaining to nuclides A, B and C respectively.
0, 1, 2, 3 = pertaining to points 0, 1, 2 and 3 in circuit.

The particular cycle to which the analysis applies is shown in Fig. 1(a). Nuclide A will be considered first. The differential equation describing the time-concentration relationship as the fuel passes through the reactor (points 0-1, time interval t_{01}) is:

$$\frac{dA}{dt} = -\lambda_a A - \sigma_a \varphi A + \gamma_a \varphi \Sigma_f = \gamma_a \Sigma_f \varphi - \lambda^*_a A \quad \ldots.(1)$$

where $$\lambda^*_a = \lambda_a + \sigma_a \varphi.$$

Integration of Equation (1) between the appropriate limits of $t = 0$ and $t = t_1$ leads to

$$A_1 = A_e \left(1 - e^{-\lambda^*_a t_{01}}\right) + A_0 e^{-\lambda_a t_{01}} \quad \ldots.(2)$$

where $$A_e = \frac{\gamma_a \Sigma_f \varphi}{\lambda^*_a}$$

A_e is the usual "equilibrium" concentration of a nuclide in a static reactor core without fuel processing.

Assuming that the time interval between exit of core and processing plant is negligible, the concentration of A at the entrance to the processing plant will be A_1 and at the exit

* Research performed under the auspices of the U.S. Atomic Energy Commission.
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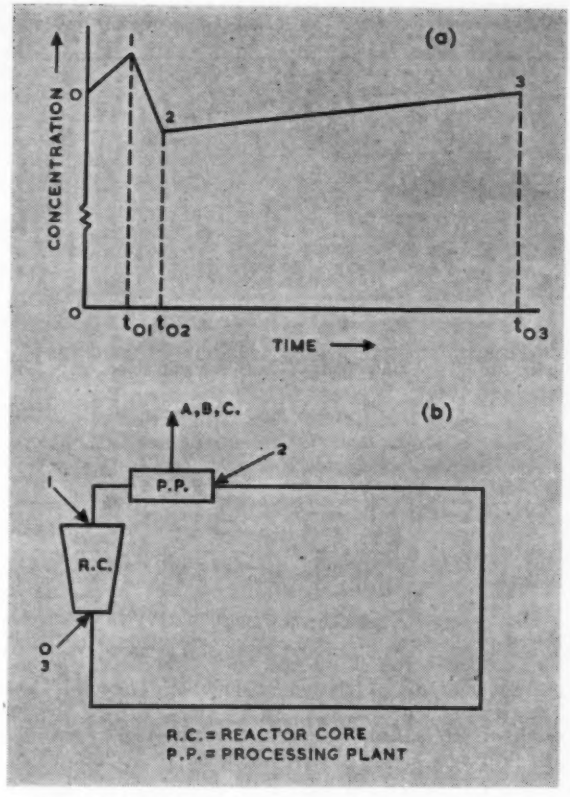

Fig. 1(a) (top): Nuclide concentration in a continuous fuel processing cycle. Fig. 1(b) (bottom). Diagram of a continuous processing system.

$$A_2 = P_a\, A_1 \qquad \ldots.(3)$$

where $0 < P_a < 1$.

In the external circuit (points 2 to 3, time interval t_{23}) the pertinent differential equation is:

$$\frac{dA}{dt} = -\lambda a\, A \qquad \ldots.(4)$$

Integration of Equation (4) in the limits $t = t_2$ to $t = t_3$ leads to:

$$A_3 = A_2\, e^{-\lambda_a t_{23}} = P_a\, A_1\, e^{-\lambda_a t_{23}} \qquad \ldots.(5)$$

In any cycle in which steady-state operation has been attained A_3 must equal A_0 and we may write:

$$A_0 = A_3 = P_a\, A_1\, e^{-\lambda_a t_{23}} \qquad \ldots.(6)$$

Combining Equations (6) and (2), one obtains:

$$A_1 = A_e \frac{1 - e^{-\lambda^*_a t_{01}}}{1 - P_a\, e^{-\lambda_a t_{23} - \lambda^*_a t_{01}}} \qquad \ldots.(7)$$

Equation (7) relates A_1, the maximum steady-state concentration of nuclide A, in a continuously processed fuel to:

(a) A_e, the maximum concentration in a stationary fuel with no processing;

(b) P_a, the efficacy of removal of A by the particular processing scheme in use; and

(c) t_{01} and t_{23}, the particular cycle under consideration.

In the usual case, one is interested in calculating the fraction of A which has to be removed in order to maintain A_1, the highest concentration in the loop, at a given value. For this purpose, Equation (7) is rewritten as follows:

$$P_a = \frac{A_1 - A_e\left(1 - e^{-\lambda^*_a t_{01}}\right)}{A_1\, e^{-\lambda_a t_{23} - \lambda^*_a t_{01}}} \qquad \ldots.(7a)$$

or:

$$\text{Fraction removed} = 1 - P_a = 1 - \frac{A_1 - A_e\left(1 - e^{-\lambda^*_a t_{01}}\right)}{A_1\, e^{-\lambda_a t_{23} - \lambda_a t_{01}}} \qquad \ldots.(7b)$$

In the case of no removal $1 - P_a = 0$ or $P_a = 1$.

Equation (7) becomes:

$$A_1 = A_e \left\{ \frac{1 - e^{-\lambda^*_a t_{01}}}{1 - e^{-(\lambda^*_a t_{01} + \lambda_a t_{23})}} \right\} \qquad \ldots.(7c)$$

Since the values of λt encountered in practice are usually very small, it is permissible to expand $e^{-\lambda t}$ in series of λt and omit terms higher than the second. In this way, one may modify Equation (7c) to:

$$A_1 = A_e \frac{\lambda^*_a t_{01}}{\lambda^*_a t_{01} + \lambda_a t_{23}} = A_{max} \qquad \ldots.(7d)$$

The concentration A_{max} is the highest concentration of A which may result in a reactor with circulating fuel with no processing.

It should be noted that when the nuclide under consideration is one which has a low thermal neutron capture cross-section $\lambda^*_a \approx \lambda_a$ and:

$$A_{max} = A_e \frac{t_{01}}{t_{01} + t_{23}} \qquad \ldots.(7e)$$

Going to the other extreme and considering the case of a 100% efficient removal system, i.e., $P_a = 0$, we see that Equation (7) becomes identical to Equation (2) when one sets $A_0 = 0$. The equation obtained in this way, namely:

$$A_1 = A_e\left(1 - e^{-\lambda^*_a t_{01}}\right) \qquad \ldots.(7f)$$

may be recognised as the typical equation applicable to a fuel element freshly charged in a reactor.

The second member of the chain will now be considered. The differential equation for nuclide B in the core is:

$$\frac{dB}{dt} = \lambda_a A + \gamma_B \Sigma_f \varphi - \lambda_B B - \sigma_B \varphi B \qquad \ldots.(8)$$

Integration of Equation (8) in the limits $t = 0$ to $t = t_1$ leads to:

$$B_1 = B_e\left(1 - e^{-\lambda^*_B t_{01}}\right) + B_0\, e^{-\lambda^*_B t_{01}} + \frac{\lambda_a}{\lambda^*_B - \lambda^*_a}(A_e - A_0)\left(e^{-\lambda_B t_{01}} - e^{-\lambda^*_a t_{01}}\right) \qquad \ldots.(9)$$

where $$B_e = \frac{\lambda_a A_e + \gamma_B \Sigma_f \varphi}{\lambda^*_B}$$

and $$\lambda^*_B = \lambda_B + \sigma_B \varphi.$$

As in the case of nuclide A, it is supposed that the processing system for B removes a fraction $1 - P_B$ of nuclide B every cycle. Then at the exit of the purification system the concentration of B will be:

$$B_2 = P_b\, B_1 \qquad \ldots.(10)$$

In the external loop (points 2 to 3) B decays to C, but in the same time new B is formed from the decay of A so that the concentration at point 3 is given by:

$$B_3 = \frac{\lambda_a}{\lambda_B - \lambda_a} P_a\, A_1\left(e^{-\lambda_a t_{23}} - e^{-\lambda_B t_{23}}\right) + P_B\, B_1\, e^{-\lambda_B t_{23}} \qquad \ldots.(11)$$

let $$z = \frac{P_a\, A_1}{P_b\, B_1} = \frac{A_2}{B_2}$$

Then Equation (11) may be rewritten as:

$$B_3 = \frac{\lambda_a}{\lambda_B - \lambda_a} \cdot z \cdot P_B \cdot B_1 \left(e^{-\lambda_a t_{23}} - e^{-\lambda_B t_{23}}\right) + P_B B_1 e^{-\lambda_B t_{23}} \quad \ldots.(11a)$$

Noting that $B_3 = B_0$ and combining Equations (11a) and (9), one obtains:

$$B_1 = \frac{K}{1 - P_B(\alpha z + \beta)} \quad \ldots.(12)$$

where:

$$K = B_e \left(1 - e^{-\lambda^*_B t_{01}}\right) + \frac{\lambda^*_a}{\lambda^*_B - \lambda^*_a} A_e \left(e^{-\lambda^*_B t_{01}} - e^{-\lambda^*_a t_{01}}\right) \quad \ldots.(13)$$

$$\alpha = \frac{\lambda_a}{\lambda_B - \lambda_a}\left(e^{-\lambda_a t_{23}} - e^{-\lambda_B t_{23}}\right) e^{-\lambda_B^* t_{01}} - \frac{\lambda^*_a}{\lambda_B^* - \lambda^*_a} e^{-\lambda_a t_{23}} \left(e^{-\lambda^*_B t_{01}} - e^{-\lambda^*_a t_{01}}\right) \quad \ldots.(14)$$

$$\beta = e^{-\lambda_B t_{23} - \lambda^*_B t_{01}} \quad \ldots.(15)$$

Expanding as before $e^{-\lambda t}$ in powers of λt and ignoring terms after the second, one simplifies Equations (13), (14) and (15) to:

$$K = \gamma_B \Sigma_f \varphi t_{01} \quad \ldots.(13a)$$

$$\alpha = \lambda_a t_{23}(1 - \lambda^*_B t_{01}) + \lambda_a^* t_{01}(1 - \lambda_a t_{23}) \quad \ldots.(14a)$$

$$\beta = 1 - \lambda_B t_{23} - \lambda^*_B t_{01} \quad \ldots.(15a)$$

It should be noted that Equation (13a) cannot be used when $\gamma_B = 0$. In such a case one should use Equation (13).

For any given cycle K, α and β are constants. This means that B_1 is a function of P_b and of Z, i.e., depends on the rates of removal of both nuclides A and B. The dependence of the concentration of a nuclide on the rate of removal of its precursor is, of course, obvious. Equation (12), however, gives this dependence in exact quantitative terms and shows that the rate of removal and concentration of a nuclide depend on the same quantities for its precursor. This becomes obvious from the definition of Z. The importance of the relationship expressed by Equation (12) cannot be overestimated, especially in the case of chains in which the precursor and the daughter vary greatly in physical and/or chemical properties as, for instance in the case of the 135 chain.

Xe^{135} with an absorption cross-section of $(2.7 \pm 0.3) \times 10^5$ barns is the most important poison encountered in reactor fuels. It is a noble gas and its removal can be accomplished only by physical means such as vacuum desorption or gas sparging. In certain fuel systems, however, its solubility and diffusivity may be such as would make a gas desorption system impractical. Iodine, on the other hand, is a highly reactive halogen, and may conceivably be removed by a more convenient chemical treatment.

Setting $P_b = 1$ in Equation (12) leads to the maximum value of B_1, i.e., the value corresponding to no removal of B in the processing plant. It is worth while noting that B_1 is not necessarily the highest concentration of B in the whole circuit. In the case of a nuclide with a very high absorption cross-section, such as Xe^{135}, the highest concentration may occur at the end of the external circuit (point 3, Fig. 1b). The situation is identical to the familiar Xe^{135} build-up in a fixed fuel element reactor after shut-down. In general, however, one is concerned with the concentration of poisons within the core and this concentration is given by Equation (12).

The change of concentration of nuclide C in the core is given by:

$$\frac{dC}{dt} = \lambda_b B - \sigma_c \varphi C \quad \ldots.(16)$$

Integration of Equation (16) between the limits $t = 0$ and $t = t_1$ leads to:

$$C_1 = \lambda_B \left[\frac{B_e}{\sigma_c \varphi}\left(1 - e^{\sigma_c \varphi t_{01}}\right) + \frac{B_e - B_0 - l}{\sigma_c \varphi \lambda_B}\left(e^{\sigma_2 \varphi t_{01}} - e^{-\lambda^*_B t_{01}}\right) + \frac{l}{\sigma_c \varphi - \lambda^*_a} \cdot \left(e^{\sigma_c \varphi t_{01}} - e^{\lambda^*_a t_{01}}\right)\right] + C_0 e^{-\sigma \varphi t_{01}} \quad \ldots.(17)$$

where $l = \frac{\lambda^*_a}{\lambda^*_B - \lambda^*_a} A_e - A_0$

In the processing section the concentration of C is decreased to:

$$C_2 = P_c C_1 \quad \ldots.(18)$$

It may be shown that the concentration of C at the end of the external loop (point 3) is given by:

$$C_3 = C_0 = C_2 + \left[\frac{\lambda_a A_2}{\lambda_B - \lambda_a} - B_2\right]\left[e^{-\lambda_B t_{23}} - 1\right] - \frac{\lambda_B A_2}{\lambda_B - \lambda_a}\left[e^{-\lambda_a t_{23}} - 1\right] \quad \ldots.(19)$$

The value of C_0 given by Equation (19) can then be placed in Equation (17) in a manner identical to that used for nuclides A and B, in order to determine the concentrations and removal rates under conditions of steady state. The resulting equation is, however, quite involved and its use offers no advantages over a trial-and-error procedure.

A problem closely connected to the concentrations of fission products is that of their poisoning effect. The rigorous procedure would involve the use of an average concentration in the core given by

$$A_m = \frac{\int_0^{t_{01}} A dt}{\int_0^{t_0} dt} \quad \ldots.(20)$$

In practice, however, the use of an arithmetic average of the core entrance and exit concentrations would lead to results fully within the accuracy of the usual absorption cross-section data.

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ERRATA TO PREVIOUS ISSUES

THE FOLLOWING CORRECTIONS to the article on the "Application of Automatic Process Control to Chemical Engineering—Part 5", published in our December 1957 issue, should be noted. These are as follows: Line 5, p. 673, should read:

$$= \frac{972 \cdot}{(307.6 - 180)} = 7.62 \text{ lb. p.h. steam} = q_s$$

The seventh line from the end of the article should read:
3 + 3.48 = **314.08°F**, with a corresponding higher pres-

In the text accompanying Nomogram No. 20, published in our January 1958 issue, the eighth line should have read as follows: "... obtained by extending the join of points on 'D', 'J' to **'H'**. Allowance ...".

On p. 93 of the February 1958 issue, in the report of the discussion on the Rescol Air Process, the cost of tonnage oxygen (line 16, column two) should have been **£4.7**.

The Universal Decimal Classification number heading the article entitled "Fouling in Heat Exchangers" (March 1958 issue, p. 141) should have read **621-71 : 620.193**.

The corrections concerned are printed in bold face type.

621.039; 541.28

CHEMICAL ASPECTS OF NUCLEAR REACTORS—PART 2†

Methods for reprocessing spent reactor fuels and reactor coolant practices described during the past year are reviewed. The work of the U.K.A.E.A. is excluded from this survey

by J. BURKETT, F.L.A.

Fuel Processing

The cost of storing spent fuel has to be balanced against the costs of processing, refabrication and shielding in the determination of the optimum fuel cycle. ULLMANN and ARNOLD[25] consider these factors for various fuels and the one- and two-region reactor types. The general aspects of chemical processing peculiar to radioactive plants is discussed by NICHOLLS and SPENCE.[26] In considering the relationship of technical and economic factors with the various types of process, they account for the composition of the fuel, degree of irradiation, fuel inventory, etc. Nuclear reactors and fuel elements are not likely to become standardised for some time; consequently, there will be a need for versatility in processing plants. Solvent-extraction processes are favoured during the next few years.

CHARPIE and others present full details of a chemical reprocessing plant designed for Oak Ridge.[27] Many aspects of reprocessing of irradiated fuels were covered at a symposium held at Oak Ridge.[28]

KETZLACH[29] discusses some of the problems to be considered in the design and operation of plant for spent reactor fuel reprocessing. Methods for the decontamination of processing plants are described by SADOWSKI.[30] In a review of the control of radioactive contamination, MALVICINI and POLVANI comment on the methods and criteria to be followed.[31]

Procedures have been proposed for the chemical decontamination of the Pressurised Water Reactor, among which are the feed-and-bleed with minimum system changes, feed-and-bleed with system changes, fill-and-flush with minimum system changes and, again, with system changes. The solutions to be used are described.[32]

ALTER and others have reported[33] on a one-cycle process for the recovery and decontamination of plutonium. They present the chemical bases of the process flowsheet. BUYERS describes a pyrochemical method of recycling plutonium using molten UF_4 as the transfer medium.[34] The fused fluorides can remove all but traces of plutonium and 95 to 100% of the fission products (except R_u) from molten uranium. ROHRMANN[35] discusses the process engineering problems in the Hanford separation plant where uranium and plutonium are separated and purified and finally prepared for shipment. He describes the processes and economics of the plant. FAUGERAS and RESNAUT give details of the results obtained at the pilot plant at Chatillon for the extraction of plutonium.[36]

New processes based on solvent extraction rather than by precipitation have been developed requiring the conversion of solid-fuel material to an aqueous feed in a nitric-acid system. The nitrate solutions are contacted with an organic solvent. Solvent extraction has been modified to handle fuels incorporating such materials as zirconium and stainless steel. ANDERSON[37] outlines the original "Redox" process and the improved "Purex" process and discusses the Zircex head-end method for U or Th clad or alloyed with Zr and the Darex head-end process for stainless-steel-uranium fuels. In the design and operation of aqueous separation plants there are a number of process variables affecting nuclear safety that have to be considered. KETZLACH[38] gives examples of how these are applied, in addition to general rules for their application to ensure a critically-safe plant operation. SAVOLAINEN and BLANCO[39] describe the preparation of reactor fuels for aqueous processing. The Darex process uses dilute *aqua regia* as a head-end process for dissolving all types of stainless-steel fuel and the elimination of chloride by distillation prior to solvent extraction. The Zircex process applies hydrochlorination reactions for processing all types of zirconium-bearing fuels. A gas-phase or liquid-phase medium may be used. FELDMAN[40] considers the application of aqueous processes to Fast Breeder Reactor blanket processing using a uranium dioxide blanket and a plutonium salt or dioxide.

GRESKY describes the Thorex process[41] which separates and decontaminates the U-233 and Pa-233 from neutron-irradiated thorium. The process was designed primarily for the processing of aluminium-clad thorium slugs, but it can be modified for use with other reactor materials. The use of solvent extraction for the refining and purification of thorium is covered by EWING and others[42] and SMUTZ and others.[43]

The principles of new processes for the extraction from leach slurries containing up to 60% uranium are surveyed by SHAW and LONG, who present tables for estimating equipment costs.[44] ROSENBAUM and others[45] report on a number of innovations in the processing of uranium ores. These include solvent extraction of sulphuric acid eluate, char-in-pulp, pressure oxidation leaching, hydrogen pre-

† *Part 1 of this review of the 1957 literature was published in the March issue, pp. 152-3.*

cipitation of uranium from soda-ash solution, thick slurry solvent extraction, ammonium carbonate leaching and non-aqueous extraction.

DEJONGHE and D'HONT studied the elimination of ruthenium from residual radioactive waters by treatment with ferrous sulphate. They also report on the elimination of hexavalent uranium with tannic acid and with trisodic phosphate.[46]

STRAUGHN and TARPLEY[47] investigated the feasibility of ultrasonic liquid-liquid extraction with a number of liquid systems including $UO_2(NO_3)_2$-HNO_3 and TBP in kerosene. They explored ultrasonic emulsification followed by ultrasonic emulsion breaking as an approach to mixer-settler contactors, and established the laboratory feasibility of an ultrasonic multistage extractor.

BASEL and KOSLAV[48] propose an oxide-slagging method for handling 18,000 kg a year of enriched uranium alloy at 79 dollars a kg. Decay time is two days after removal from the reactor as compared with the normal time of three to four months.

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Nuclear Reactor Coolants

Various systems of heat removal from nuclear reactors have been classified by CHIRKIN[61] in which water, boiling water, aqueous solutions, gas and liquid metals are used as coolants. ROTTENBURG discusses the properties necessary in heat-transfer media for use at elevated temperatures.[62] He surveys and tabulates the physical properties of commercially available media: Aroclors, Bectherm, Dowtherm, heat-transfer salt, hydrocarbon oils, liquid metals—lead, mercury, sodium and potassium—and water. PARKINS[63] sets out the advantages and disadvantages of liquid metals, organic liquids, gas and water in relation to such factors as neutron absorption and scatter properties, stability to radiation decomposition and induced radioactivity.

BRAMMER[64] compares fast-reactor coolants. Calculations are given for the variation in the critical mass of the fast reactor caused by sodium, sodium-potassium, lead and mercury. Each system is calculated for uranium, ferrous, lead and bismuth reflectors.

FREUND and LONDON[65] present a general method for comparing thermal performance of fuel-element geometries and coolants for non-boiling reactors. Examples are given where water, diphenyl and carbon dioxide (at 450 psi) are coolants; and plate-channels (as in the MTR), crossed wires and sphere beds are the fuel-element geometries. CHABOSEAU[66] describes the pile arrangement and the accessory equipment for the cooling of the reactors at Marcoule.

MOELLER has made a study of reactor cooling systems[67] with the purpose of identifying and controlling the radionuclides in the reactor cooling water at various stages in a recirculating type of system.

Gas Coolants

FORTESCUE comments on the influence of gas properties on the choice of working gas for a high-temperature gas-cooled reactor.[68] He describes the interrelationships of pumping power, heat output and the design features for various gases. BEALE[69] evaluates the merits and disadvantages of using carbon dioxide, hydrogen, nitrogen and air as coolants. In an examination of some of the characteristics of gas-cooled reactors where fuel cans use circumferential fins or grossly roughened surfaces, FORTESCUE[70] presents a method of estimating the effect of changes in fin material and coolant on heat transfer. Among the chemical problems associated with the use of gases in the gas-cooled graphite-moderated reactor, DENNIS[71] emphasises the nature of the complex side reactions that may be expected and the difficulty of exact estimation of gas composition likely to occur during operation.

Liquid Metal Coolants

BOADLE[72] outlines the physical and nuclear properties of liquid metals as an aid to the selection of heat-transfer media. He includes lithium, sodium, potassium, Na-K eutectic alloy, mercury, lead, bismuth, Pb-Bi eutectic alloy. Among the handling problems is the particular one of the choice of pumps. A review of existing liquid-metal-cooled reactors concludes.

The specific heats of liquid metals and salts are reviewed by DOUGLAS,[73] who also presents a method for the approximate prediction where no data exists.

From 1950-55, investigations were carried out at the U.S.S.R. Academy of Sciences to determine the thermal properties and heat-transfer characteristics of the alkali metals. NOVIKOV and others[74] comment on the principal results of the studies which included the behaviour of liquid sodium in turbulent flow through circular copper and nickel tubing. Methods of measuring viscosity, thermal diffusivity and density of liquid metals are described. HARTNETT and IRVINE[75] estimate the turbulent heat-transfer performance of liquid metal flowing through passages having non-circular cross-sections.

EGGEN and others[76] describe the problems encountered in the design and development of some of the coolant components for the Sodium Reactor Experiment. The heat-transfer systems are dealt with in detail. Methods for determining the coolant flow in the SRE fuel elements are reviewed by FREEDE and SHIMAZAKI[77].

Organic Coolants

A survey was carried out of the use made by a number of industrial concerns of organic heat-transfer media. BARKER[78] reports on the correlation of data from 118 companies giving a representative cross-section of successful industrial practices. Apart from the attractive properties of organic compounds for use as a moderator/coolant, there are some unfavourable heat-transfer characteristics. SHIMAZAKI and ANDERSON[79] discuss the relationship between coolant channel geometry, thermal power and pressure drop in a surface temperature limited system, the change in heat-transfer coefficient due to radiolytic damage, burn-out heat flux and thermal stress problems.

According to PURDY,[80] diphenyl as a reactor coolant appears to permit thermodynamical cycles with reasonable thermal efficiency and volume flow. If it proves feasible to use lower condenser pressures, the diphenyl turbine may equal the efficiency of the steam turbine. Recent experiments by FROMM and ANDERSON[81] indicate that organic materials such as diphenyl may be sufficiently resistant to radiation damage to act as satisfactory coolants. Data are given on vapour pressure, density, specific heat, viscosity,

thermal conductivity and heat transfer. SATO[82] investigated polyphenyl coolants to establish the burn-out limit of liquid diphenyl for various flow conditions.

BOYD and others,[83] working with isopropyl biphenyl and biphenyl with and without additions of water and hydrogen at 600 to 800°F, report on the corrosion behaviour of zirconium base materials, hafnium, high-strength aluminium alloys and stainless steels. BARKER and MAUSTELLER,[84] working with biphenyl at a temperature of 800°F and a surge tank pressure of 300 psig, tested samples of zirconium, zircaloy, hafnium, stainless steel, Alcoa aluminium alloys and carbon steels. The steels and the aluminium alloys were found to be relatively unaffected.

COLICHMAN and FISH[85] submitted terphenyls to temperatures of from 400 to 450°C and radiation doses up to 90 watt-h/g, thereby approaching reactor operating conditions. The results indicate sufficient stability for use as a reactor coolant and moderator.

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Pressure Losses Through Annuli

THE calculation of pressure loss for the steady turbulent flow of a fluid through smooth tubing is usually carried out by means of the Fanning equation in which the friction factor is a function of the Reynolds number. For conduits of non-circular cross-section, attempts have been made in the past to use the Fanning equation and to base the Reynolds number upon an equivalent diameter = 4 × the hydraulic radius. Unless, however, the skin friction in the annular space or duct is equal at all points on the wetted perimeter, this assumption is a rough approximation. For parallel plates, simulated in practice by rectangular passages of high aspect ratio, this procedure is a fair approximation.

A recent paper by WALKER, WHAN and ROTHFUS[1] describes experimental work and derives correlations of practical use for determining pressure losses through friction for steady isothermal flow through smooth annuli and rectangular ducts. They propose a procedure which enables pressure losses through smooth annuli to be estimated with about the same precision as for smooth tubes.

The authors use the concept of radius of maximum velocity, r_m, for estimating a new hydraulic radius. At this radial distance the velocity profile goes through a maximum and the local shear stress is zero. For any arbitrary radius r, the cross-sectional area occupied by the fluid is $\pi (r^2 - r_m^2)$ and the wetted perimeter over which fluid shear is exerted is $2\pi r$. Thus:

$$R_{H_2} = \frac{r_2^2 - r_m^2}{2r_2} = \tfrac{1}{4}De_2 \qquad \ldots . (1)$$

where r_2 = radius of outer surface (ft);
De_2 = equivalent diameter (ft);
R_{H_2} = hydraulic radius referred to outer surface (ft);
$r_m = \dfrac{r_2^2 - r_1^2}{ln\left(\dfrac{r_2}{r_1}\right)^2}$; and
r_1 = radius of inner surface (ft).

The outer surface is the more important for the purposes of the correlation.

For estimating the pressure loss, the Reynolds number must be based on De_2 and the first step is to determine the flow régime. A series of charts is provided (Figs. 1A-1H of Ref. E) for this purpose and an additional plot (Fig. 3, Ref. 1) also gives the variation of the upper and lower critical values of Re with the radius ratio r_1/r_2. The approximate figures of Table I have been obtained from the latter source (Fig. 3).

TABLE 1

Radius Ratio $\frac{r_1}{r_2}$	0.0	0.2	0.4	0.6	0.8	1.0
Reynolds No.						
Lower Critical Value	2000	2200	2350	2450	2620	2750
Upper Critical Value	2800	3000	3050	3170	3250	3400

Once the régime is determined, assuming it does not lie in the transition zone but is either viscous or turbulent, then in the case of the latter the friction factor (f_2) can be determined in the range Re_2 3000-100,000, from:

$$f_2 = 0.079\ Re_2^{-0.25} \qquad \ldots . (2)$$

and the frictional pressure loss calculated from:

$$\triangle p = \frac{2 f_2 \rho V^2 L}{g_o De_2} \qquad \ldots . (3)$$

where ρ = fluid density (lb/cu. ft);
V = fluid velocity (ft/sec.);
g_o = conversion factor 32.2 lb. mass ft/lb force sec^2; and
L = length of section (ft).

For viscous flow the friction factor is given by

$$f_2 = \frac{16}{Re_2}\left[\frac{(r_2^2 - r_m^2)^2}{r_2^2 (r_2^2 + r_1^2 - 2r_m^2)}\right] \qquad \ldots . (4)$$

and the pressure loss is estimated by Equation (3).

It is shown that the friction factor obtained by using an equivalent diameter = 4 × cross-sectional area ÷ wetted perimeter is related to the friction factor by:

$$\frac{f \text{ actual}}{f \text{ hydraulic radius}} = \left[\frac{2\left(1 - \dfrac{r_1}{r_2}\right) ln \dfrac{r_2}{r_1}}{\left(\dfrac{r_1}{r_2}\right)^2 - 1 + 2\, ln \dfrac{r_2}{r_1}}\right]^{1\cdot25}$$

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MAJOR REVIEWS

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Elements of Heat Transfer†

A review by Prof. M. W. THRING

THE second edition of this book appeared in 1950 while MAX JAKOB was still alive, and it is a tribute to the usefulness of his work that a third edition has now appeared. It is a book written primarily for undergraduates in chemical and mechanical engineering who wish to have a good working knowledge of the subject and to be able to carry out practical heat-transfer calculations without necessarily understanding the full details of the fundamental theory involved. The use of examples from common observation to introduce a given mechanism of heat transfer is clearly a good method for teaching undergraduates. Thus, for example, aerodynamic heating is illustrated by the shooting star, and even the topical problem of designing ballistic objects which may re-enter the earth's atmosphere without being destroyed is mentioned. The analogue between electrical and thermal circuits for various methods of heat flow is regularly used in the book, although this analogue must be used with considerable caution, since there is nothing equivalent to inductance in the thermal circuit.

The value of the book as a reference work for practical calculations is greatly enhanced by the provision of a special list of tables and one of figures needed for numerical calculations although, in the reviewer's opinion, it is a pity to give a figure for the emissivity of CO_2 without one also for the emissivity of water vapour which generally makes a higher contribution to the emissivity of the combusion gases from practicable fuels. The idea of including a chapter on the experimental determination of conductivities and emissivities is excellent, but unfortunately the chapter is only six pages and does not touch at all on such problems as the measurement of emissivity of refractory surfaces at high temperatures, using, for example, the method developed by MICHAUD in France. A simple and clear account is given of the relation between heat transfer and fluid friction using the Reynolds analogy, and there is a chapter on mass transfer limiting the discussion, however, to mass transfer by ordinary diffusion and by forced and free convection.

The book follows the American text-book style of giving a large number of problems at the end of each chapter before the references, and these will clearly be a great advantage in teaching the subject by the tutorial method. It can thus be said that the book successfully achieves what it sets out to do, namely, to provide a clear and straightforward text-book on the experiments of heat transfer without going too deeply into either the mathematics or the physics of the subject.

† *By M. Jakob and G. A. Hawkins. Third edition. Chapman & Hall, London, 1957, 342 pp., 54s.*

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Pilot Plants, Models and Scale-up Methods*

A review by Prof. P. V. DANCKWERTS

THE study and practice of chemical engineering are taking on (even in this country) an increasingly scientific aspect. We are paying closer regard to the detailed mechanisms of the processes which occur in our plants, in the hope of improving or predicting performance by insight rather than by trial and error. The process designer would like to be in the same position as the bridge designer: that is, to be able to do his design work on paper, with complete confidence in the results and without the necessity for grossly-inflated margins of safety. However, the fundamental physical factors involved in a typical process-design problem are often more numerous and less susceptible to precise analysis than in the case of the structural design of a bridge. In fact, a detailed study of the operation of a mixer, solvent-extraction plant or fluidised-bed reactor may sometimes induce despair of making useful quantitative predictions from first principles. This is probably a defeatist attitude to adopt; nevertheless, many of the most useful concepts are found to be derived from broad generalisations rather than from detailed mechanistic theories.

One of the most fertile sources for the chemical engineer has been the field relating to the principles of similarity, and including the use of models, procedures for scaling up or down, and the formulation of general statements or quantitative relationships in terms of dimensionless ratios. The power of these methods in dealing with intractable problems in fluid mechanics has been recognised since the pioneering work of FROUDE and OSBORNE REYNOLDS. They have also been widely applied to the process of heat-transfer between fluids and solids, and to formulating quantitative analogies between heat, mass and momentum transfer. It has become a general practice to express the empirical formulæ of chemical engineering in terms of dimensionless ratios, thus giving them the greatest possible generality.

However, in the case of the more complicated processes with which the chemical engineer is concerned—for instance, heterogeneous catalytic reactions—the application of the principles of similarity is difficult because of the large number of criteria of similarity which are in-

* *McGraw-Hill Series in Chemical Engineering (Sydney D. Kirkpatrick, Consulting Editor) by R. Edgeworth Johnstone and M. W. Thring, McGraw-Hill Publishing Ltd., New York and London, 1957, 307 pp., 74s.*

volved. To formulate these is usually simple enough; to satisfy them all simultaneously in a model is often impossible. A more sophisticated approach is then necessary if useful information is to be obtained from models.

The book under review is the first to be devoted to the application of similarity to process plant, and the authors have on the whole made good use of their unique opportunity. They are both well qualified, by virtue of industrial experience and scientific outlook, to expound the practical applications as well as the basic principles of the subject.

The book opens with a discussion of the role of pilot plants and models in process development. This is followed by chapters on the principle of similarity, the techniques of dimensional analysis, and the derivation of the relevant dimensionless variables from the differential equations describing the process. Although this part of the book may be regarded as more or less standard, the choice of examples (for instance, the flow of granular solids, dimensional processes and chemical reactions) already marks it as a work addressed primarily to the chemical and process engineer; and the authors find it necessary to introduce certain novel concepts, such as that of "homologous" systems in which chemical compositions and physical properties are the same at corresponding points. This section of the book constitutes a sound and sensible introduction to the subject, developed logically but without undue pedantry.

Perhaps one of the most important chapters in the book is that on "The Régime Concept". The blind application of the principles of similarity, as already stated, is frequently sterile because of the impossibility of satisfying all criteria simultaneously. This difficulty can often be avoided if it is recognised that the process (in both plant and model) is conditioned only by certain of these criteria, provided the others have values above or below a certain limit. This approach requires a deeper insight into the problem than the uncritical use of dimensional analysis, but often makes it possible to construct a model which is similar *in its essentials* to the plant. An extension of this principle is the use of models which are "doctored"—for instance, by the use of geometrical distortion or dummy heat-transfer surfaces to preserve thermal similarity in reactors. A similar theme is discussed in the chapter on boundary effects.

The second half of the book is concerned with the applications of the principles to various situations encountered in process engineering—for instance, fluid flow in pipes and channels, filtration, heat transfer, packed columns, mixers, reactors, furnaces and kilns. The emphasis is rather uneven; no doubt this is partly due to the fact that similarity can be more easily and profitably applied to some fields than to others, and partly to accident in the sense that investigators with a taste for the subject happen to have worked in certain fields. However, it is also possible that the personal interests of the authors have had an influence. The chapter on furnaces and kilns, as is to be expected, is one of the most comprehensive and authoritative in the book. On the whole, the shortcomings in the applications to particular processes reflect the lack of constructive work in these fields, and should act as a stimulus to research and development workers. For instance, the chapter on "Mixing Equipment" is concerned largely with the power required to drive impellers or paddles at specified speeds. The question of the characterisation of mixtures and of the performance of mixers, and the problem of investigating these by means of models appears to be an almost virgin field for some enterprising investigator.

It is heartening to see a book of this kind, which breaks fresh ground in the literature of chemical engineering, written by British authors. They are to be congratulated on producing a text-book which deserves the widest circulation both in industry and in the academic world. It may not be perfect, but it compares more than favourably with many other books in the same series and with chemical engineering texts in general.

British Chemical Plant*

THE majority of mechanical and chemical engineers in the chemical and processing industries, whether their duties relate to design, maintenance or management, at some time or other need to consult makers of mechanical plant. Indeed, the reasons which may motivate such an approach may be diverse; it may be that a comparatively small piece of equipment such as a pump or valve has to be replaced, or a new vessel may be required to rep'ace a worn-out one or a plant may be required for an entirely new process. Many chemical manufacturers have their own design departments and drawing offices and much of their equipment they either make themselves or have made by an outside firm to their own designs. Other smaller firms rely on a single chemical engineer or a small body of engineers to produce basic specifications for plant. Then there are the processing firms without any design facilities who rely upon plant makers entirely for their equipment.

But whatever the need in the way of plant may be, the latest edition of the British Chemical Plant Manufacturers' publication "British Chemical Plant" will provide a valuable guide to the suppliers of equipment in this country. For this volume embraces almost all the important chemical plant makers in the United Kingdom, including fabricators who construct solely to customers' designs, others who design to meet customers' needs and a whole host of firms whose interests lie in the manufacture of "specialised" installations such as multi-effect evaporators and combustion and heat transfer equipment. Then there are the others who devote their interests to smaller components including pumps and valves, and those whose métier is pipework design and erection.

For the large undertaking whose interests may lie in an entire plant, there is information about the activities of a number of contractors who are able to supply, for example, complete plants for synthesis gas, sulphuric and nitric acids and plants for the gasification of coal and oil among others.

The volume is excellently illustrated and, in this respect, surpasses the high standard set by its predecessor. The illustrations are often useful, especially to the newcomer to chemical engineering, and for the erperienced designer they contain a number of useful practical pointers. The growth of constructions for atomic-power projects is amply reflected in the new edition.

The various services offered by members of the B.C.P.M.A. are outlined in a useful classified index of products and services included at the latter end of the book. This enables an interested party, whether French, German or Spanish, to find the name of a manufacturer of the particular piece of equipment in which he is interested. This book, which is something more than a directory of chemical plant makers, deserves a place of prominence in every design office.

* The fourteenth edition of directory of members of the British Chemical Plant Manufacturers.

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HOW TO CORRELATE VISCOSITY DATA

An easily-constructed form of graph paper can be used for correlating viscosity, temperature and concentration data of inorganic salt solution

by Prof. D. S. DAVIS*

WHEN, for one purpose or another, it is necessary to correlate viscosity-temperature-concentration data for alkalis and aqueous solutions of inorganic salts, one seeks some method of plotting that will yield a series of straight isotherms. Natural scale plots of viscosity η versus concentration F result in lines of considerable curvature. Plotting the logarithm of viscosity versus concentration straightens the isotherms considerably, but they still show too much curvature.

When the sine of ten times the viscosity in centipoises is plotted against concentration on semilogarithmic paper (with concentration on the natural scale) the isotherms often become straight over wide ranges. This method of plotting log *sin* 10η versus F was first employed[1] for aqueous solutions of sodium carbonate at normalities of 1 to 6, temperatures of 22.5° to 98°C, and viscosities of 0.3 to 6 centipoises.

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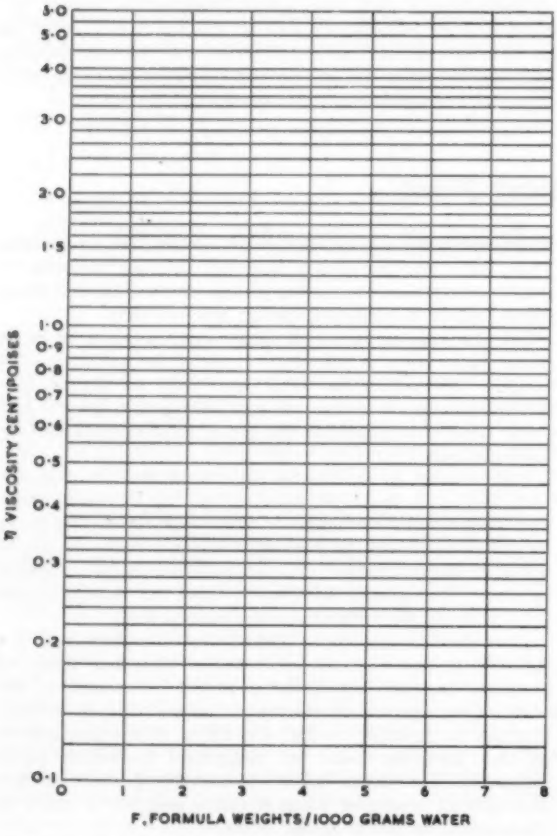

Fig. 1. Example of special plotting paper which avoids the need to refer to trigonometrical tables.

Fig. 2 on semilogarithmic paper, shows how satisfactory the method is when applied to data[2] for two alkalis, and for several chlorides, nitrates and sulphates. The arrows near the chemical formulæ direct the reader to the low-range concentration scale at the top; for other compounds, one uses the high-range concentration scale at the bottom. The isotherms for potassium hydroxide show slight curvature over a range of 8 formula weights per kilogram of water, but can be considered to be essentially straight over ranges of 2 or 3 such units. From the nature of the sine function, viscosities should be less than 6 centipoises.

Fig. 1 illustrates special plotting paper that relieves one of the necessity of looking up the sines of ten times the viscosities. Thus, one has only to consider viscosities and concentrations when using Fig. 1. Anyone can construct his own special viscosity plotting paper from the following tables:

η, cp	Distance from η=0.1 cp, cm	η, cp	Distance from η=0.1 cp, cm
0.10	0.00	1.0	14.97
0.12	1.18	1.1	15.59
0.14	2.19	1.2	16.14
0.16	3.06	1.3	16.65
0.18	3.83	1.4	17.13
0.20	4.52	1.5	17.57
0.22	5.14	1.6	17.97
0.24	5.70	1.7	18.36
0.26	6.23	1.8	18.72
0.28	6.70	1.9	19.07
0.30	7.17	2.0	19.38
0.32	7.58	2.2	19.98
0.34	7.97	2.4	20.51
0.36	8.35	2.6	21.00
0.38	8.70	2.8	21.45
0.40	9.04	3.0	21.86
0.45	9.80	3.2	22.23
0 50	10.47	3.4	22.59
0.55	11.10	3.6	22.91
0.60	11.66	3.8	23.21
0.65	12.18	4.0	23.49
0.70	12.66	4.5	24.11
0.75	13.11	5.0	24.63
0.80	13.53	5.5	25.07
0.85	13.92	6.0	25.44
0.90	14.28		
0.95	14.64		

Any suitable natural scale can be chosen for the horizontal concentrations.

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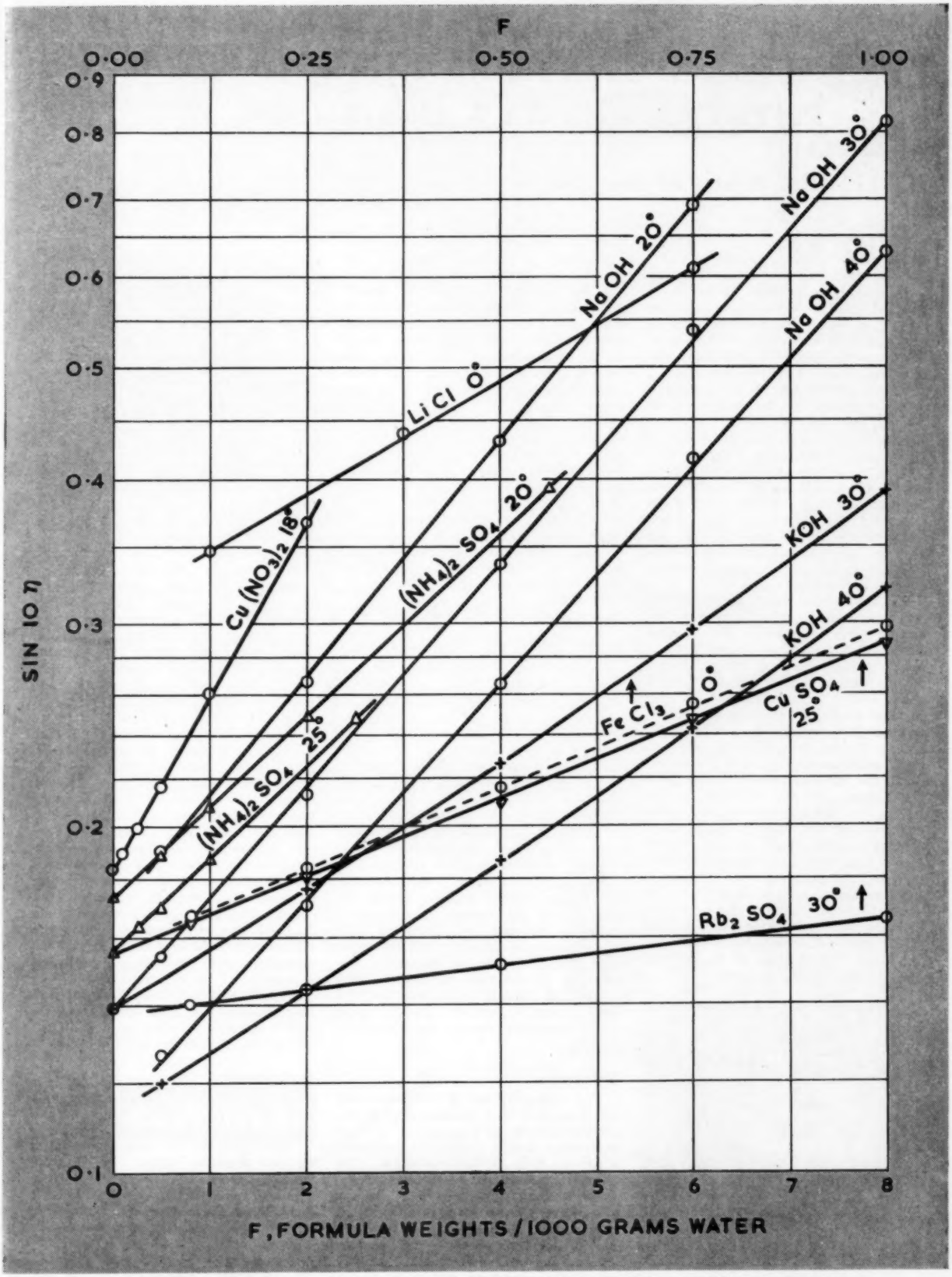


Fig. 2. Example of proposed method of correlation for inorganic salt solutions at different temperatures.

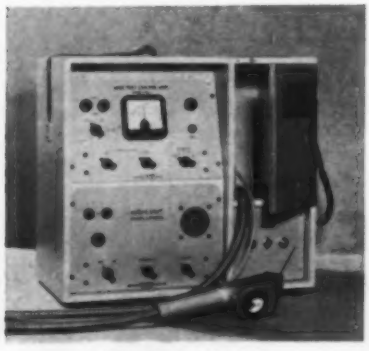
PHYSICAL SOCIETY'S EXHIBITION, 1958

A Preview of New Equipment, Instruments and Procedures

THIS year's Physical Society's exhibition which will be held, following recent custom, at the Royal Horticultural Society's Halls, Westminster, will be opened on March 24 by Professor N. F. Motts, F.R.S., Cavendish Professor of Experimental Physics, Cambridge, and President, International Union of Physics.

New equipment shown will include a prototype apparatus for the purification of organic compounds by zone-melting, developed from the original Chemical Research Laboratory apparatus by BAIRD & TATLOCK LTD., Freshwater Road, Chadwell Heath, Essex. Its action is automatic, the heating coil descending at a uniform rate to an adjustable bottom position and returning quickly to an adjustable top position, the cycle being repeated as often as desired. The equipment handles quantities of about a kilo.

EDWARDS HIGH VACUUM LTD., Crawley, will show a large four-stage oil booster-pump developed for vacuum duties requiring large throughputs at relatively high pressures during part of the pumping cycle. Its peak speed is about 4500 l./sec. for air and 9000 l./sec. for hydrogen. On the same stand will be demonstrated examples of the company's new range of single- and two-stage quiet-running pumps. The series caters for the displacement range 20 to 150 l./min., and the two-stage models incorporate the oil recirculating device demonstrated last year. A system using a high-vacuum stage of the Rootes blower type backed by conventional fore-pumping, for pumping large volumes of gases at pressures from about 10 mm to about 10^{-3} mm Hg, will also be shown, and test data on silicone pumping fluid M.S. 704 (DC704) will be available on the stand. The company is also exhibiting a high-sensitivity leak detector applicable to outward leakage and vacuum apparatus. Its sensitivity, it is claimed, is slightly less than 10^{-2} lusecs. THE BAKER DIVISION OF ENGELHARD INDUSTRIES LTD., 52 High Holborn, London, W.C.1, will show two newly developed catalytic gas purifiers for the removal of acetylene impurity from ethylene streams by selective hydrogenation.



Edwards' leak-detector.

TEXAS INSTRUMENTS LTD., Dallas Road, Bedford, will demonstrate a transistor servo remote-control system whose input is derived from a synchro generator and which can withstand temperatures up to 150°C. A precision zone-conveyor oven in which any articles up to a maximum size of 11 in. × 8 in. × 4 in. can be passed at various speeds through controlled heated zones will be shown by TOWSON & MERCER LTD., Croydon.

New Materials

New materials of construction to be on view include synthetic fused silica, the elaboration which is described by THE THERMAL SYNDICATE LTD., Wallsend, Northumberland, as their most important achievement during the year. It is stated to be made from pure silicon compounds instead of from quartz crystal, and to contain less than one part in a million of impurity. The company have also developed an aluminous porcelain sheath for use with caustic solutions and a recrystallised alumina sheath for use with hydrofluoric acid solutions.

Items of chemical plant fabricated in tantalum by seam welding and by argon-arc fusion welding will be among the exhibits in that metal, molybdenum, tungsten, niobium and zirconium products shown by MUREX LTD., Rainham, Essex; and ACCLES & POLLOCK LTD., Oldbury, Birmingham, will exhibit tubes in special metals, and examples of experimental composite tubing drawn from dissimilar metals metallurgically bonded.

Ultrasonics

The expanding use of ultrasonics will be illustrated in a number of exhibits, among them being a new range of non-destructive testing equipment by A. E. CAWKELL LTD., 6 Victory Arcade, The Broadway, Southall, Middlesex. Equipment type LDA(M) has been designed for measuring, observing or controlling changes due to hardening, temperature, stress, non-homogeneity, order-disorder effects, crystallisation, flaws, porosity, chemical composition, etc.

Cawkell's ultrasonic materials tester.

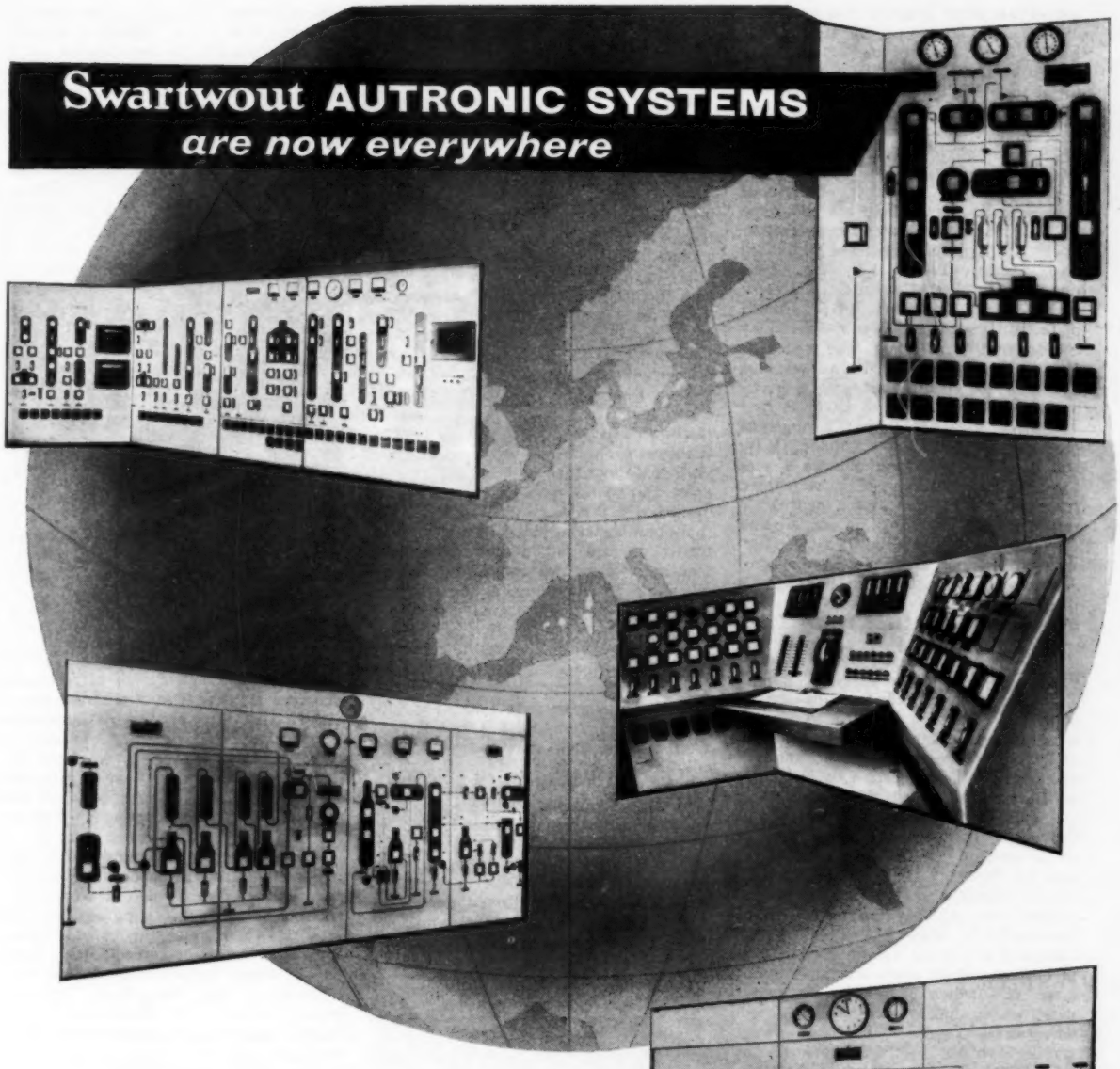
The National Physical Laboratory, Teddington, Middlesex, will show improvements in ultrasonic flaw detection by the use of a transducer made in the form of metal probe with a sandwich of three quartz crystals on it. These can be switched to test on various frequency ranges. The device then enables flaw detection to be carried out at frequencies from ¼ Mc/s up to about 7 Mc/s.

A constant temperature hot-film anemometer to be shown by LINTRONIC LTD., 149 Strand, London, W.C.2, measures and records mean and turbulent velocity components of gas or water. The sensing element, a small glass rod with the wedge end coated with very thin platinum is mounted in the flow medium. The metallic film is heated to a predetermined temperature and, when gas or water flows over it, it tends to be cooled. The operation of an electronic feedback system, however, causes the temperature to be kept constant, and the necessary increase in heating current gives a measure of the velocity over the film. The film has, it is claimed, stable physical characteristics over long working periods, and a dynamic response of $-\frac{1}{2}$ db for 10-100 KC at 1000 fps mean velocity.

Instruments

Instruments will, as usual, form a large part of the exhibition. New thermometric instruments to be shown include a thermocouple of tungsten and a tungsten-rhenium alloy, by BRITISH THOMSON-HOUSTON CO. LTD., Marconi House, Strand, London, W.C.2, suitable for the measurement of temperatures of up to 300°K. Silicon carbide-graphite thermocouples to be exhibited by the MORGAN CRUCIBLE CO. LTD., 52 Battersea Church Road, London, S.W.11, will con-

Swartwout AUTRONIC SYSTEMS
are now everywhere



Now being manufactured by Elliott Brothers (London) Ltd. Swartwout Autronic Equipment comprises miniature all-electronic units which completely eliminate transmission lags in indicating, recording and controlling circuits.

Swartwout *Autronic* CONTROL SYSTEMS

ELLIOTT

Full details from the Swartwout Division of

ELLIOTT BROTHERS (LONDON) LTD., CENTURY WORKS, LONDON, S.E.13 (TIDEWAY 1271)

A MEMBER OF THE ELLIOTT-AUTOMOTION GROUP

sist of an inner graphite rod cemented into an outer silicon carbide tube, about ¼ in. × 12 in., and, the makers say, they should be useable at temperatures of up to about 1900°C without a protective sheath. JOHNSON, MATTHEY & CO. LTD., 73 Hatton Garden, London, E.C.1, will show a range of noble-metal thermocouples.

Developments in pressure-measuring devices to be shown include a prototype of a small differential pressure transducer by ELLIOTT BROTHERS (LONDON) LTD., Century Works, Lewisham, London, S.E.13. This relies on the deflection under differential pressure of a flat steel plate, and the deflection is measured by a differential transformer. The prototype operates with a differential pressure range of 0 to 1000 lb./in.^{2} and with a maximum applied pressure of 2000 lb./in.^{2}

KELVIN HUGHES LTD., Livingstone College, Knotts Green, London, E.10, will demonstrate a force-balance system for pressure measurement, in which the force output of a pressure capsule is measured by applying an equal and opposite force from a high-precision spring to reduce the deflection to zero. An accuracy of ±0.010 in. Hg with a threshold of sensitivity of 0.004 in. Hg. for the range 0-30 in. Hg is claimed for it.

New Procedures and Research

This year new procedures to be demonstrated include two optical methods for sieve mesh examination. The calibration of special test sieves to British Standard 410 requires the projection of an image of the mesh at a magnification of 50 or 100, and the MINISTRY OF SUPPLY will show how the necessary apparatus can be conveniently mounted in a projection box by "folding" the light path with a plane mirror. An optical diffraction method for checking the mesh size of sieves will be shown by THE MORGAN CRUCIBLE CO. LTD. The method is said to be particularly applicable to sieves of large area which cannot be accommodated on normal types of shadowgraph. The Ministry will also exhibit a water-stabilised plasma jet arc that may be used to study the behaviour of materials exposed to high temperatures (up to 12,000°K) such as exist, for example, behind intense shock waves. An experimental apparatus for differential thermal analysis of chemical reactions in glass and refractory production will be exhibited by THE GENERAL ELECTRIC CO. LTD., Magnet House, Kingsway, London, W.C.2. When fitted with a radiation-collecting probe, it may be used for measuring high temperatures where the source cannot be viewed directly. The most advanced form of high-resolution nuclear magnetic resonance spectrometer elaborated by METROPOLITAN-VICKERS ELECTRICAL CO. LTD., Trafford Park, Manchester, 17, an experimental prototype of laboratory instrument, will also be shown at the exhibition.

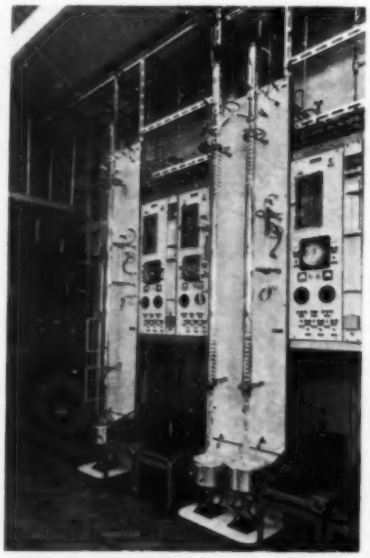
The MECHANICAL ENGINEERING RESEARCH LABORATORY of the D.S.I.R., East Kilbride, Glasgow, will show a novel apparatus for studying tension and torsion under fluid pressures up to 15,000 atmospheres (100 tons/in.^{2}) in a 1¼-in. diameter chamber.

Use of Computers

The use of computers in the solving of scientific and engineering problems will be the subject of a number of demonstrations. For example, a complete electronic analogue of a chemical plant achieved by analogue computers is being demonstrated by E.M.I. ELECTRONICS LTD., Hayes, Middlesex. The plant forms a closed loop made up of storage tanks, operating columns and connecting pipes with their associated pumps. Characteristics of each unit will be simulated. The study has been carried out on behalf of Laporte Industries Ltd. ELLIOTT BROTHERS (LONDON) LTD., Century Works, Lewisham, London, S.E.13, will show their 402F floating-point digital machine accepting various classes of problems for solution at high speed while visitors wait at their stand. The floating-point unit of the machine will deal with numbers in the range 2^{-30} to 2^{+31} with sign, numbers outside this range being treated as zero and infinity respectively. Another working analogue computer will be an Elliott Reactor simulator type ND181. This equipment, which is primarily for the instruction of nuclear engineers, has been designed to represent the operation of a nuclear reactor under a wide range of conditions.

GLASS DEVELOPMENTS LTD., 47c Sudbourne Road, London, S.W.2, will have assembled on their stand a fractionating column as used at the Research Station of the British Petroleum Co. Ltd. for separating and analysing complex petroleum mixtures and the purification of hydrocarbons and sulphur compounds.

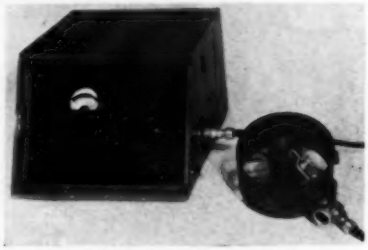
The NATIONAL INSTITUTE OF AGRICULTURAL ENGINEERING, Wrest Park, Silsoe, Beds., will show a remote-reading anemometer, developed for use in hop-dryer test work at temperatures below 120°F and required to measure very low air flow.



Fractionating columns by Glass Developments.

Newly-released designs of instruments from the U.K.A.E.A. include a quartz-crystal system for the detection of small changes in pressure and a photo-extinction particle size recorder which measures the size frequency of dust particles in the order of 1 micron.

On the opening day the exhibition will be open to members only from 10.30 a.m. to 2 p.m., and to members and visitors thereafter until 7 p.m. On the subsequent days it will be open to members and visitors for the following times: Tuesday, March 25, 10 a.m. to 9 p.m.; March 26, 10 a.m. to 7 p.m.; March 27, 10 a.m. to 4.30 p.m. Admission is by ticket.



N.I.A.E.-designed anemometer.

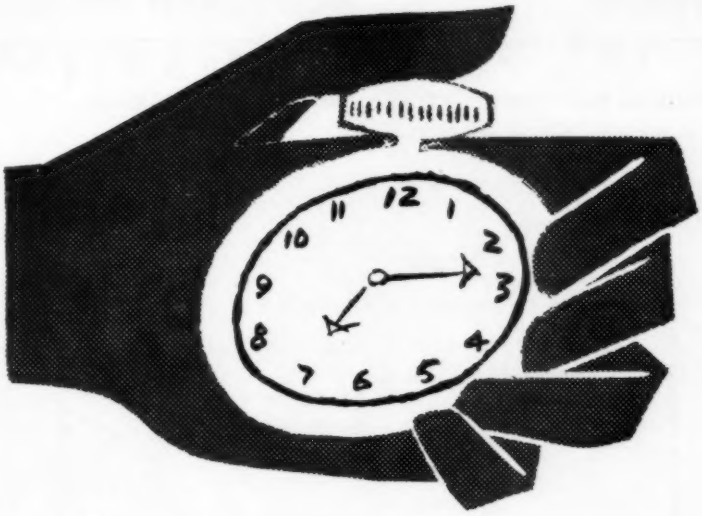
Recording Analysers

Continuous analysers that will be on show include a new design of recording gas-phase transfer type of electrochemical dissolved oxygen analyser by CAMBRIDGE INSTRUMENT CO. LTD., 13 Grosvenor Place, London, S.W.1. It employs, the makers say, a novel method of detection and it has been designed to meet the requirements of modern high-pressure and high-temperature steam systems.

A hygrometer for the range 0-1% relative humidity incorporating porous ceramic transducers which measure atmospheric humidity in terms of electrical resistance, and which can be used either for measurement or control of humidity will be shown by B.S.I.R.A., South Hill, Chislehurst. THE INFRA-RED DEVELOPMENT CO. LTD., 11 Broadwater Road, Welwyn Garden City, Herts., will show an application of an infra-red gas-analyser to measure water vapour that can be adapted for continuous plant operation. A prototype of recording photoelectric refractometer developed for making continuous accurate measurements over a large range will be seen on the stand of BELLINGHAM & STANLEY LTD., 71 Hornsey Rise, London, N. 19.

MERVYN INSTRUMENTS LTD., St. John's, Woking, Surrey, will exhibit a new recording instrument designed for the analysis of sulphur dioxide in the atmosphere in concentrations down to 0.01 part per million. The sulphur dioxide is absorbed in a reagent containing hydrogen peroxide, which oxidises the contaminant to sulphuric acid. The resulting increase in the conductivity of the solution is measured.

A portable meter for rapidly measuring the sulphur dioxide content of the atmosphere, developed by the Central Electricity Research Laboratories, will be shown by EVANS ELECTROSELENIUM LTD., North Street, Bishops Stortford, Herts.



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It's about time we told you what an excellent job the Labgear Time-Period Counter can do in time interval measurement.

This inexpensive crystal-controlled Counter Chronograph operates in the range 10—10^{-4} seconds for the accurate measurement of the time interval between two events.

An extremely flexible triggering arrangement permits the counter to be operated from:

Two consecutive pulses of common origin.

Two pulses derived from independent sources.

Mechanical contact sequence S/C Start-O/C Stop, i.e., closed during period of observation.

Mechanical contact sequence O/C Start-S/C Stop, i.e., open during period of observation.

Quartz crystal frequency 10 kc/s.—accuracy 0.02% over the temperature range −10°C to +70°C.

The normal time-count capacity of ten seconds may be extended by four digits by the addition of Register D. 4109.

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VOLUME OF LIQUID IN A CONICAL-BOTTOMED VESSEL (CONE BEING FULL)

By D. B. PURCHAS, B.Sc., A.M.I.Chem.E.

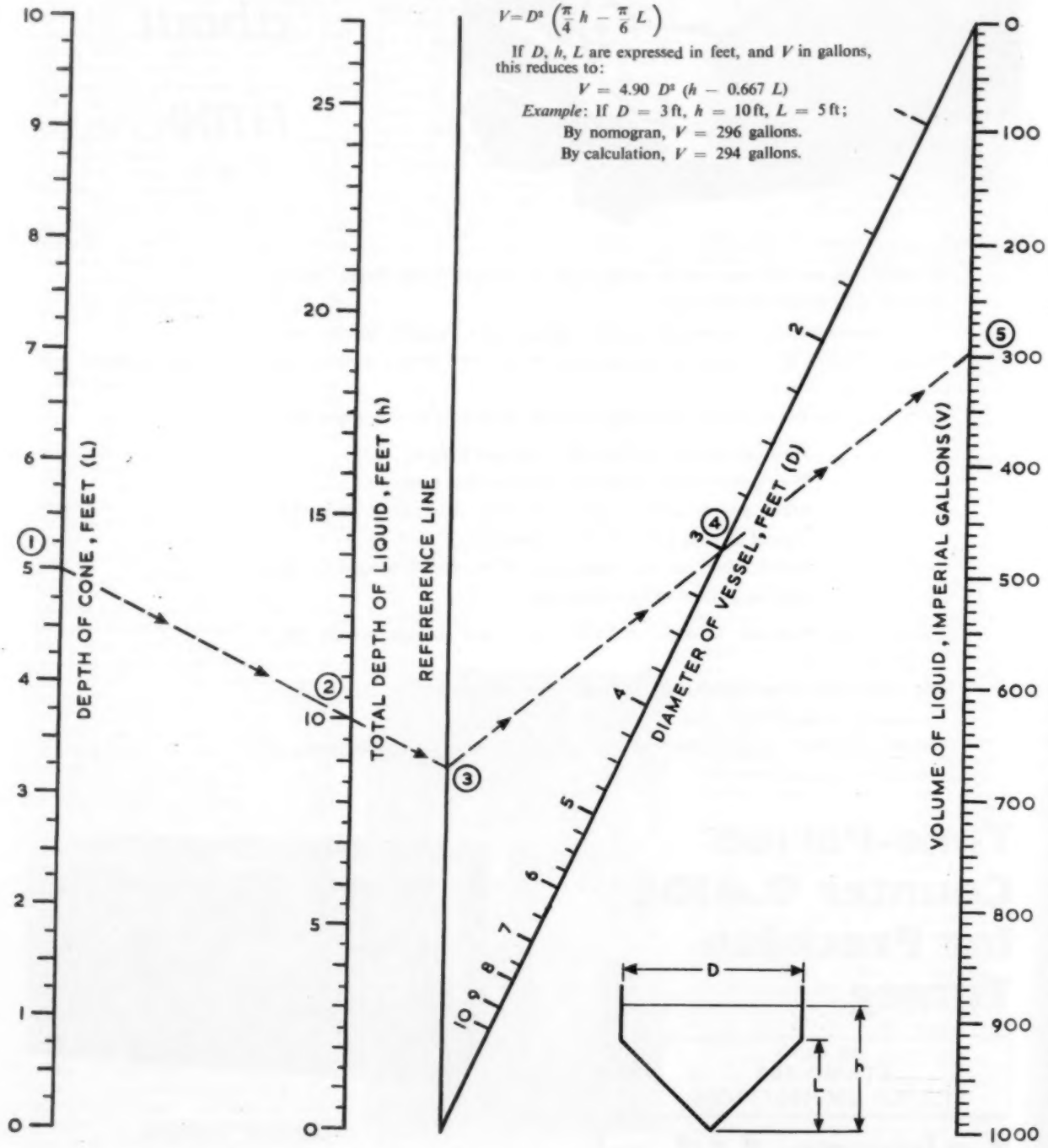
This nomogram gives the volume of liquid contained in a conical-bottomed cylindrical vessel, the cone being full. The volume, V, is equal to the sum of the volumes in the conical and in the cylindrical portions: hence

$$V = D^2 \left(\frac{\pi}{4} h - \frac{\pi}{6} L \right)$$

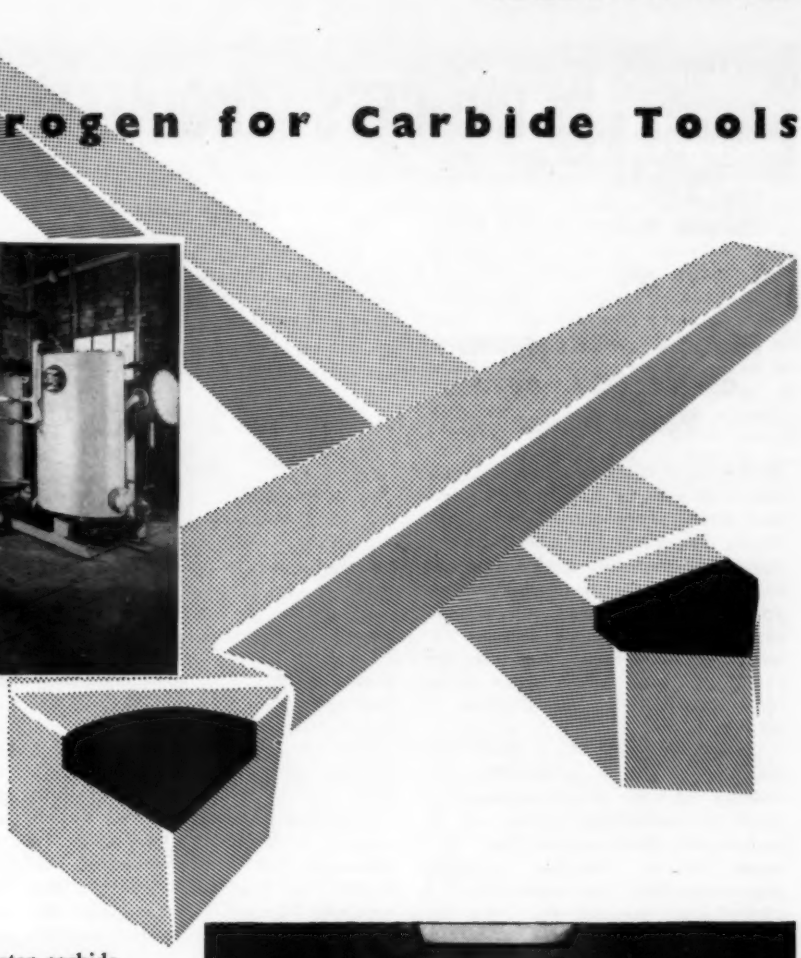
If D, h, L are expressed in feet, and V in gallons, this reduces to:

$$V = 4.90\ D^2\ (h - 0.667\ L)$$

Example: If $D = 3$ ft, $h = 10$ ft, $L = 5$ ft;
By nomogran, $V = 296$ gallons.
By calculation, $V = 294$ gallons.

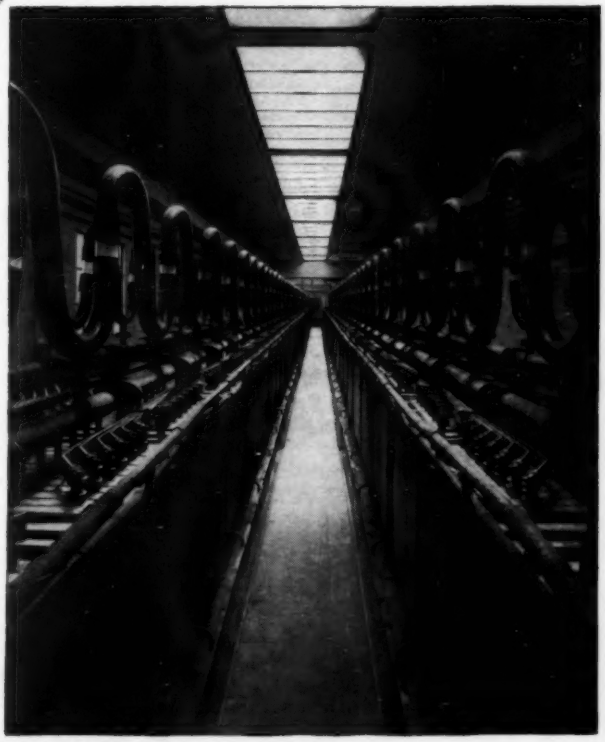


Drying Hydrogen for Carbide Tools



In the manufacture of Prolite tungsten-carbide tools, Murex Limited use Birlec adsorption dryers to remove water vapour from their electrolytic hydrogen supply.
The hydrogen is dried to a dew-point of minus 70°C for use in the reduction and sintering furnaces and the high quality of the product depends on the stringent moisture control.
Birlec moisture adsorbers are available in a range of standard sizes for varied industrial applications including the drying of compressed air and the dehumidification of factories and stores.

Illustration above:—
Birlec adsorbers for hydrogen drying.
Illustration right:—
Electrolytic hydrogen plant at Murex Limited.



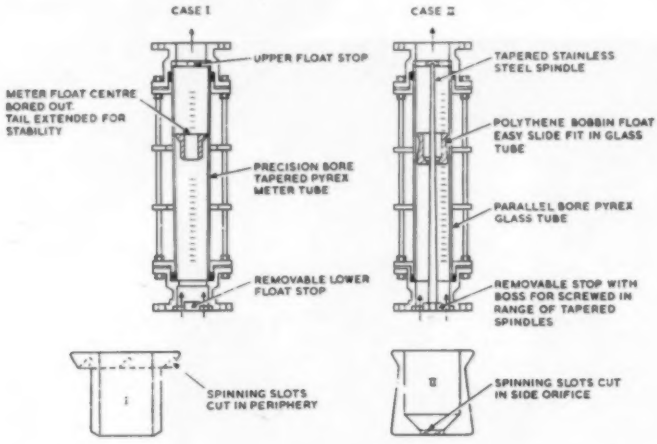
BIRLEC ADSORPTION DRYERS
DRY AIR & GASES

DRYER DIVISION OF
BIRLEC LIMITED
An A.E.I. Company
ERDINGTON · BIRMINGHAM 24

LONDON · SHEFFIELD · GLASGOW · NEWCASTLE-ON-TYNE

PROCESS ENGINEER'S NOTEBOOK

Plant Modifications on Variable-area Flowmeters


CASE I
CASE II
UPPER FLOAT STOP
METER FLOAT CENTRE BORED OUT TAIL EXTENDED FOR STABILITY
PRECISION BORE TAPERED PYREX METER TUBE
REMOVABLE LOWER FLOAT STOP
SPINNING SLOTS CUT IN PERIPHERY
TAPERED STAINLESS STEEL SPINDLE
POLYTHENE BOBBIN FLOAT EASY SLIDE FIT IN GLASS TUBE
PARALLEL BORE PYREX GLASS TUBE
REMOVABLE STOP WITH BOSS FOR SCREWED IN RANGE OF TAPERED SPINDLES
SPINNING SLOTS CUT IN SIDE ORIFICE

ROTAMETERS or variable-area flow meters in sizes up to 3 in. N.B. pipeline size have become almost first choice on chemical plants where a visible and manually controllable rate of flow at Reynolds numbers below approximately 10,000 and at low capital cost is required. Certain disadvantages in operation, however, led to the following modifications, which have proved very satisfactory in service.

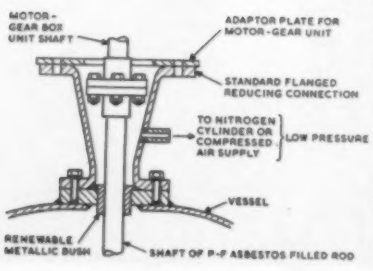
Case 1. A visible flow meter was required to give a controllable flow reading but with minimum head loss. After a considerable number of experimental modifications had been tried without success, including measurements of the expansion of a bed of glass beads, it was found that the following modification to a standard rotameter operated with every satisfaction. The float, of the plumb-bob pattern, had the centre portion completely removed as showin in the sketch. This enabled operation of the flowmeter with the same quantity of liquor as before but with very little head loss, due to the large reduction in velocity in the tube. Since the increase in area was a constant and the ratio of float volume to area had been altered only slightly, the meter required recalibrating for only one point on the scale and this recalibration was then successfully used throughout the range.

Case 2. Flowmeter required for manual control of (1) opaque milky fluid; and (2) opaque dark fluid. Both these liquors contained a certain amount of finely dispersed solid. An extended stem with a magnetic follower was tried and, though this operated successfully when clean, difficulty was experienced due to sediment causing binding of the extended stem in the tube. The inverted modification as shown in the sketch was made up in the workshop and operated quite satisfactorily. The flow tube consisted of an ordinary straight-sided piece of laboratory Pyrex tube. The central taper spindle was turned in the shop and the floats machined for (1) in black industrial polythene, and (2) in white opaque industrial polythene. With these floats and taper spindles, both rotameters operated satisfactorily after calibration and identification with a linear scale.

The following advantages were realised: (a) The float lip, being immediately adjacent to the glass in all positions, was always visible, particularly in view of the contrasting colour of the plastic float and the liquor. (b) The float operated almost as a piston and kept the bore of the tube clean and free from sediment. (c) Any sediment settling out of the liquor could not be retained in the instrument and no sticking due to this was ever experienced. (d) The glass tubes which burst in the winter time in exposed positions, in the rotameter taper tube, were expensive items and frequently not immediately available ex stock in the particular size required. This straight-tube modification could be drawn immediately from laboratory stores at the cost of a few pence.

F. MOLYNEUX

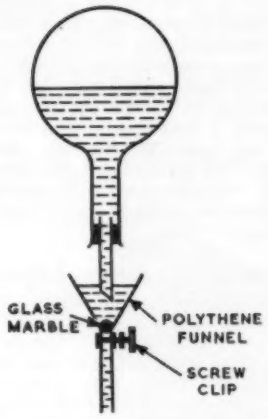
Avoiding a Gland on an Agitated Vessel


MOTOR-GEAR BOX UNIT SHAFT
ADAPTOR PLATE FOR MOTOR-GEAR UNIT
STANDARD FLANGED REDUCING CONNECTION
TO NITROGEN CYLINDER OR COMPRESSED AIR SUPPLY
LOW PRESSURE
VESSEL
RENEWABLE METALLIC BUSH
SHAFT OF P-F ASBESTOS FILLED ROD

THE ACCOMPANYING DIAGRAM shows a cheap way of avoiding glands, severe agitator shaft wear and consequent leakage at glands in a small vessel processing corrosive materials. The use of a standard flanged-reducing or flanged-expansion connection with an adapter plate at the larger flange provides a cheap support for mounting the motor or motor-gear unit. The agitator shaft is constructed from a rod of asbestos-filled phenolic-plastic. This possesses excellent resistance to many corrosive fluids and it stands up well to abrasion. The renewable metal bush through which the shaft passes can be constructed of suitably resistant material such as 18/8/4Mo stainless steel. A side connection is screwed or welded to the reducing connector for a supply of compressed air or nitrogen which is used if a fire hazard exists at the plant. The pressure of either gas supply is set by means of a reducing valve to a point 2 to 3 psi above the working pressure of the vessel.

Improved Drip Feeder

IN THE STERILISATION of small rural water supplies by the addition of dilute sodium hypochlorite solutions it is often necessary to use drip-feed apparatus. Where the hypochlorite solution is diluted by water of any appreciable hardness there is deposition of lime salts which leads to choking of the fine jets or orifices. Such choking can, of course, arise from the presence of other suspended matter. Because apparatus of this sort has frequently to be left in the care of unskilled labour, the clearing of blockages must be as simple an operation as possible, as also must be the re-setting of the drip feed. A simple way of achieving this is to use a "chicken-feeder" arrangement with the delivery discharging into a polythene funnel. In the apex of the funnel a glass marble of suitable diameter is placed so that flow of solution is blocked or is no more than a very slow drip. If the stem of the polythene funnel just below the marble is held in a screw clip it will be found that the drip feed can be controlled to any desired rate by adjusting the pressure of the clip. The purpose of

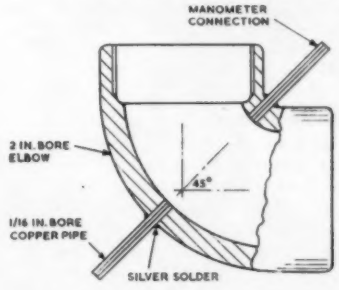


this adjustment is to cause slight distortion of the funnel where the marble is sitting. Clearing of any blockages is performed quite simply by pushing a pencil or glass rod up the stem of the funnel so as to lift the marble and allow a flush of solution for a moment or two. The apparatus is applicable to any process requiring the regular application of very small quantities of chemical solutions.

A. T. PALIN.

Device for Measuring Air Flow

THE FOLLOWING simple device has been found useful for the indication and approximate measurement of air flow. When a fluid passes through an elbow bend a pressure difference is created across the cross-section, varying from a larger value at the largest radius via a maximum to a lower value at the smallest radius. By using small-bore connections at these two points, this pressure difference can be measured on, say, a water gauge. A difference in levels on such a gauge therefore indicates that air (or gas or liquid) is flowing and, if such an installation is calibrated against a flow-

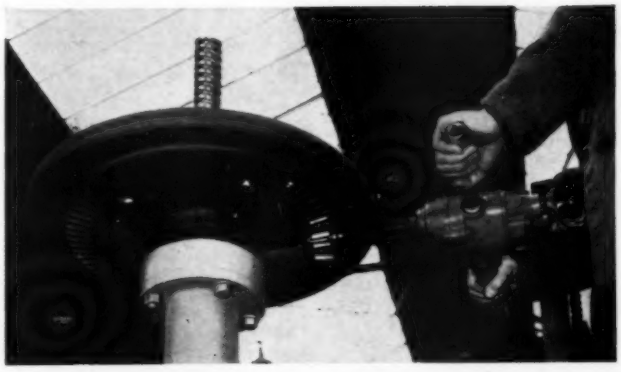


meter, it can also be used for reasonably accurate flow measurement and control.

Where great accuracy is not essential, such a device has the advantage of being simpler to construct on site and of causing a smaller pressure drop than a more expensive orifice plate fitting. The theoretical treatment of this subject (for water flow) is described in "Bulletin No. 289 of the University of Illinois Engineering Experiment Station", December 22, 1936.

J. GRANVILLE

The Labour-saving Valve



(Courtesy W. C. Holmes Ltd.)

AT PLANTS handling large volumes of gases, large pipelines and valves have to be used—it is not uncommon for valves of 48-in. bore to be installed. The manual adjustment of large valves is something of a problem and often requires considerable physical effort. The photograph shows one way of overcoming this difficulty without incurring the expense of a valve fitted with a compressed-air cylinder or motor. To the underside of the hand wheel of the external screw-type valve a crown wheel is fitted. The pinion is turned by a portable compressed air drill. With this method of operation it is possible to open or close a large valve within 30 sec. without the expenditure of any human effort. This is a useful method where automatic operation is not necessary.

Contributions invited

THE EDITOR invites readers to submit, for possible publication in "Process Engineer's Notebook", notes on practical devices that have been elaborated on the job for improving the operation or increasing the safety of processes, or that have been extemporised in special circumstances. The contributions preferably should be of about 250-500 words, and be illustrated with a line diagram or sketch, or a photograph. A minimum of three guineas will be paid for each contribution used. They will be published anonymously or under the contributor's name, according to his wishes.

World of Chemicals

Sulphuric Acid Production and Uses

Production of sulphuric acid in the United Kingdom last year in plants of members of the National Sulphuric Acid Association rose to 2,335,891 tons, 84,711 tons more than in 1956, despite a smaller production capacity (2,775,690 tons against 2,785,300) due to a reduction in the installed capacity of chamber process plants. The plant in use was utilised to the extent of 84.2% of capacity, however, compared with 80.8% in 1956. The largest trade uses of the acid were for the manufacture of superphosphates, 22.93% of the total consumption (23.13% in 1956); sulphate of ammonia, 13.38% (13.33%); titanium dioxide, 13.26% (12.17%) (a total of 314,306 tons was used for this, 15% more than in 1956); and rayon and transparent paper, 11.75% (11.93%).

Japanese Refinery

The first catalytic re-forming unit in Japan designed to produce a 90 clear octane blending component went on stream at the refinery of Asia Oil Co. Ltd., Yokohama, recently. Of Universal Oil Products' design, it is combined with a unifying unit processing naphtha from Middle East crudes, and it has a design capacity of 1500 barrels a day.

Rubber and Plastics in Holland

The Bataafsche Petroleum Maatschappij (B.P.M.), of the Royal Dutch Shell Group, have decided to go ahead with the plans for the construction at Pernis of a general-purpose synthetic rubber plant with an initial capacity of at least 50,000 tons per year. Both butadiene and styrene types of synthetic rubber will be produced. A new company has been formed by the B. F. Goodrich Chemical Co. and the Algemene Kunstzijde Unie N.V. (A.K.U.) of Arnhem for the manufacture of butadiene-styrene latex, high styrene reinforced polymer and Hycar nitrile latex. Design and construction work on the necessary plant is beginning at once and its completion is scheduled for May, 1959. In the plastics field, the Netherlands State Mines have begun the construction of a new factory for the large-scale production of polyethylene by the I.C.I. high-pressure process at the rate of 7000 tons yearly. The product will be marketed under the name Stamylan. For some time States Mines have been manufacturing polyethylene in a pilot plant by the low-pressure Ziegler process.

Electronically Instrumented Refinery

Three electronically and hydraulically instrumented refinery units, said to be the first of their kind in the world, went on stream recently at the plant of Regent Refining (Canada) Ltd., at Port Credit, Ontario. The units are a catalytic cracker, a polymerisation unit and gas concentration equipment. The cracker, one of the largest "stacked" units ever built, has a design capacity of 7000 barrels a day of fresh charge consisting of a blend of atmospheric and vacuum gas oils, and it is designed to operate at 65% conversion with a coke-burning capacity of 90001b. per hour. The chamber polymerisation unit will produce 730 barrels a day of de-butanised polymer gasoline. The units were designed by Universal Oil Products Co.

Expansion at Lujan de Cuyo Refinery

The Argentine Government has approved a contract with Kellogg's Co. for the expansion of an oil refinery at Lujan de Cuyo, Argentina. The new plant will consist of a 28,000-BPSD crude distillation unit, an 18,500-BPSD delayed coker and an 11,000-BPSD Orthoflow catalytic cracker and gas recovery unit, in addition to a utility plant, crude tankage, transfer lines and pumps. Feedstocks will be Barrancas crude, a waxy, low-sulphur-content crude produced in the area.

New Synthetic Rubber Plant

A new plant at Beaumont, Texas, U.S.A., is now producing Hypalon synthetic rubber chlorosulphonated polyethylene at the rate of 15 million pounds per year. It replaces limited facilities at Charleston, West Virginia.

Austrian Petrochemicals

Farbwerke Hoechst A.G., Frankfurt, together with an Austrian associate, are planning the erection of a petrochemical plant at Schwechat, near Vienna, where the Austrian Mineral Oil Authorities propose building a new oil refinery.

Gallium Recovery

A new process for recovering gallium announced by The Dow Chemical Co. involves treating subdivided ore containing the metallic element with a current of hydrogen chloride or hydrogen bromide under substantially anhydrous conditions at 700-950°C. The gallium is volatilised as the trihalide, and is condensed and recovered. The process has been elaborated by Drs. L. K. Frevel and J. T. Kummer, and it is covered by U.S. Patent No. 2,823,096.

Montecatini Sales

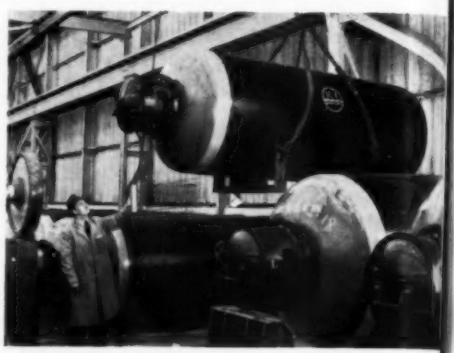
Sales of the Montecatini group for 1957 exceeded by lire 14,000 million (£8 million) those of the previous year (about lire 152,000 million) (£87 million). Total exports amounted to about lire 44,000 million (£25 million), an increase of about 12% over those of 1956.

Titanium Impeller Experience

A titanium impeller in use in a slurry containing cobalt, nickel, copper arsenic, iron sulphuric acid and iron arsenic compounds at the Colera Mining installation at Garfield, Utah, has been found on inspection after four years' operation to be "almost unaffected". The reaction was carried out at temperatures of more than 400°F and at pressures of 500-600 psi.

Dutch Expansion in Ireland

Koninklijke Industrieele Maatschappij have concluded an agreement with the Sligo County Council to erect a chemical plant in Sligo, after negotiations with the Irish Industrial Development Authority had led to a substantial Government grant being made for the building. The company proposes to manufacture there the chemicals for which they already have a market. The processes will be chiefly electrolytic, and the products destined for continental and other countries.



The largest steel cylinders so far to be used in Great Britain for the transport of anhydrous ammonia were brought into use at I.C.I.'s Dowlais factory recently. Designed by the company's Billingham Division, they achieve a considerable saving in weight of metal in relation to weight of ammonia transported. They hold 2 tons of ammonia with a total weight of 4 tons, against the 5¼ cwt. content of ammonia with a total of about 15 cwt. of the previous largest cylinders in use.

Synthetic Rubber

The production of the new synthetic Coral rubber which is described as "practically identical to natural rubber" has been taken beyond the pilot-plant stage by Firestone Tyre & Rubber in the U.S.A., but it is not yet to be made on a commercial scale.

First Nigerian Petroleum

The first cargo of crude oil to be exported from Nigeria left Port Harcourt recently bound for Rotterdam, where it was to be discharged at Shell's Pernis refinery.

Italian Nuclear Congress

The Fifth International Congress and Exhibition of Electronics and Nuclear Energy, Rome, has been postponed until June 16 to 30, 1958. The sections will now be held on the following dates: Nuclear, June 16 to 20; Electronics, June 22 to 28.

Eire Antibiotic Plant

Antigen Ltd. have opened a new antibiotic unit at Rosecrea, Co. Tipperary.

Australian Pharmaceutical Plant

The Roussel Group of France, which specialises in the manufacture of drugs, antibiotics and hormones, is planning to establish a factory in Sydney.

People who pride themselves on their good equipment speak of ENSECOTE in a personal way. ENSECOTE protective plastic linings can be applied almost anywhere to almost anything. They are easily cleaned and sterilised, completely odourless, tasteless —and economical to install because larger vessels can be lined on the spot. ENSECOTE is particularly useful, too, for renovating glass lined tanks. The Dairy, Brewing, Paper and Chemical industries— and all who own rail and road storage tanks—will find ENSECOTE invaluable as a protection against wastage due to deterioration.

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Book Reviews

Physico-chemical Effects of Pressure
by S. D. Hamann
Butterworths, London, 1957, 246 pp., 42s.

THE past two or three decades have seen a steady increase in the number of full-scale chemical processes employing pressures of hundreds of atmospheres. To what may be regarded as the traditional syntheses of ammonia, methanol and urea have been added hydrogenation, hydration, alkylation, hydroformylation and other catalytic processes for tonnage manufacture of organic chemicals. More recently, the production of polythene and artificial diamonds registers entry into a higher range of pressures, stimulated to a large extent by fundamental work at 10^5 to 10^5 atmospheres. Since BRIDGMAN's pioneer researches, study of the physics and chemistry of extra-high pressures has become widespread and techniques more varied. DR. HAMANN's excellent and timely review, enlivened as it is by a consistent thermodynamic and kinetic approach, gives a clear general introduction to the field. It is aimed primarily at the graduate chemist and chemical engineer and is as much an exercise in physical chemistry as a digest of results. At the same time, it is soundly documented (there are 582 references) so that the expert or informed reader is also supplied with a handy pocket-book.

A brief opening chapter emphasises the thermodynamic outlook; we are fore-armed with LE CHATELIER's principle and ideas of molecular order which serve throughout the text. Some 30 pages are then devoted to apparatus and techniques reaching up to 200,000 atmospheres. Though well illustrated and practical, this chapter is highly condensed and requires filling out from other sources. The main body of the book is divided almost equally between physical and chemical topics, but the sequence and treatment are such as to make the transition smooth. Four chapters deal with the following physical subjects: volumetric effects in pure substances, mixtures and matter at very high pressures; phase changes in one- and two-component systems; transport properties (viscosity, diffusion and thermal conduction) and transmission of sound; and dielectric and optical effects. In this group, molecular interaction theory and quantum ideas are constructively introduced. The influence of structure and bonding on response to pressure is also indicated.

Chemical topics are discussed in three chapters on electrolytic conduction, chemical equilibrium and reaction kinetics. These offer a systematic picture of the relation between molar volume change and pressure effects. The application of rate theory to the author's classification of reaction types, including those in which charge transfer, partial bonding, solvation and orientation play a part, is particularly satisfying. In the event, the classification of 21 types of reaction ceases to be a catalogue and becomes a convenient vehicle for discussing all the factors concerned in forming the transition complex. The final chapter on miscellaneous effects is something of an afterthought, but is nonetheless valuable in summarising, among other things, more recent information on electronic and structural transformations in solids, high-pressure polymerisations and mineral syntheses. A book of this style and purpose has long been overdue. DR. HAMANN is to be congratulated on filling the gap so well.

N. LEVY

Experimental Designs—Second Edition
by William G. Cochran and Gertrude M. Cox
John Wiley & Sons Inc., New York; Chapman & Hall Ltd., London, 611 pp., 82s.

MOST engineering and applied science courses today contain a subject such as "Introduction to Statistics", which deals with some elements of probability theory and its application to product control, simple significance tests and an introduction to experimental design. However, the average chemical engineer in industry, attempting to elucidate the controlling factors and optimum conditions for a reaction, soon realises that his knowledge is inadequate to design the more complex experiments required to solve his problems. In "Experimental Designs", COCHRAN and COX have provided the standard text-book for the applied statistician in industry. Furthermore, the subject is dealt with in a manner understandable by the scientist and engineer with the background provided by the better undergraduate courses.

As in the first edition, the present one is introduced by a chapter on planning experiments. This is followed by a discussion of methods of increasing the accuracy of experiments by using replications and some notes on the analysis of the results obtained. It is the briefness of this section which makes the book difficult to use by those without previous training in statistics. The subsequent ten chapters are devoted to a systematic exposition of the various aspects of design: factorial experiments, latin squares, blocks, lattice squares and the other accessories of the applied statistician. The examples are drawn mainly, as usual in statistics text-books, from agriculture and biology, such as the effect of trace elements on lettuce growth. It remains the task of the chemical engineer to substitute runs, temperatures and pressures, reaction times and additions of reactants for plots, treatments, varieties and additions of manure or trace elements when applying the designs to chemical plant problems.

Detailed plans of the designs follow the appropriate chapters, and extensive tables of random permutations a section on tests of randomness. Appended to all chapters are bibliographies where the original papers from which the numerical examples have been taken are given, as well as the most important papers which deal with special aspects of the preceding chapter.

This edition varies from its predecessor with the addition of two new chapters: 6A, which is a complete account of fractional replication of factorial experiments; and 8A, which discusses factorial designs where the factors are quantitative variables, the study of response surfaces and the line of steepest ascent. More colloquially this means the evaluation of optimum process conditions. This new edition will assure its authors the continued use of their book for courses in advanced experimental design and as the handbook of the statistician in industry.

W. STRAUSS

Rühren, Betriebstechnik
by F. Kneule
Dechema, Frankfurt-am-Main, Germany, 1957. 50 pp., D.M.20 (34s., app.); D.M.16 (27s. app.) to Dechema members.

IT can scarcely be for cheapness that such a valuable monograph on stirring methods and equipment is published in the flimsy binding of the "Dechema-Erfahrungsaustausch" series. Presumably only a small circulation was expected. Yet the work fully achieves its claimed object of facilitating the choice of a suitable stirring method for particular cases. The various types of stirring mechanism are classified and described in accordance with their construction and operation. Terms and formulæ are elucidated. The whole forms a complete survey of the possibilities of all stirring mechanisms now available. Separate tables are provided to assist selection of stirrers for miscible liquids, immiscible liquids, liquids with small quantities of solid and liquids with large quantities of solid. The brochure closes with some worked examples of designs of stirring mechanisms, the data for which were obtained from experiments made with models and which can be applied without difficulty to the solution of practical problems. Included are reproductions of relevant German standards, defining stirrer terminology, forms, dimensions and speeds of rotation. As with all publications in the "Dechema-Erfahrungsaustausch" series, this brochure is privately published by the Dechema and can only be obtained directly from that organisation. It deserves a wider circulation in a more durable binding.

Statistics of Non-ferrous Metals, 1954-56
1957, 124 pp., 12s.

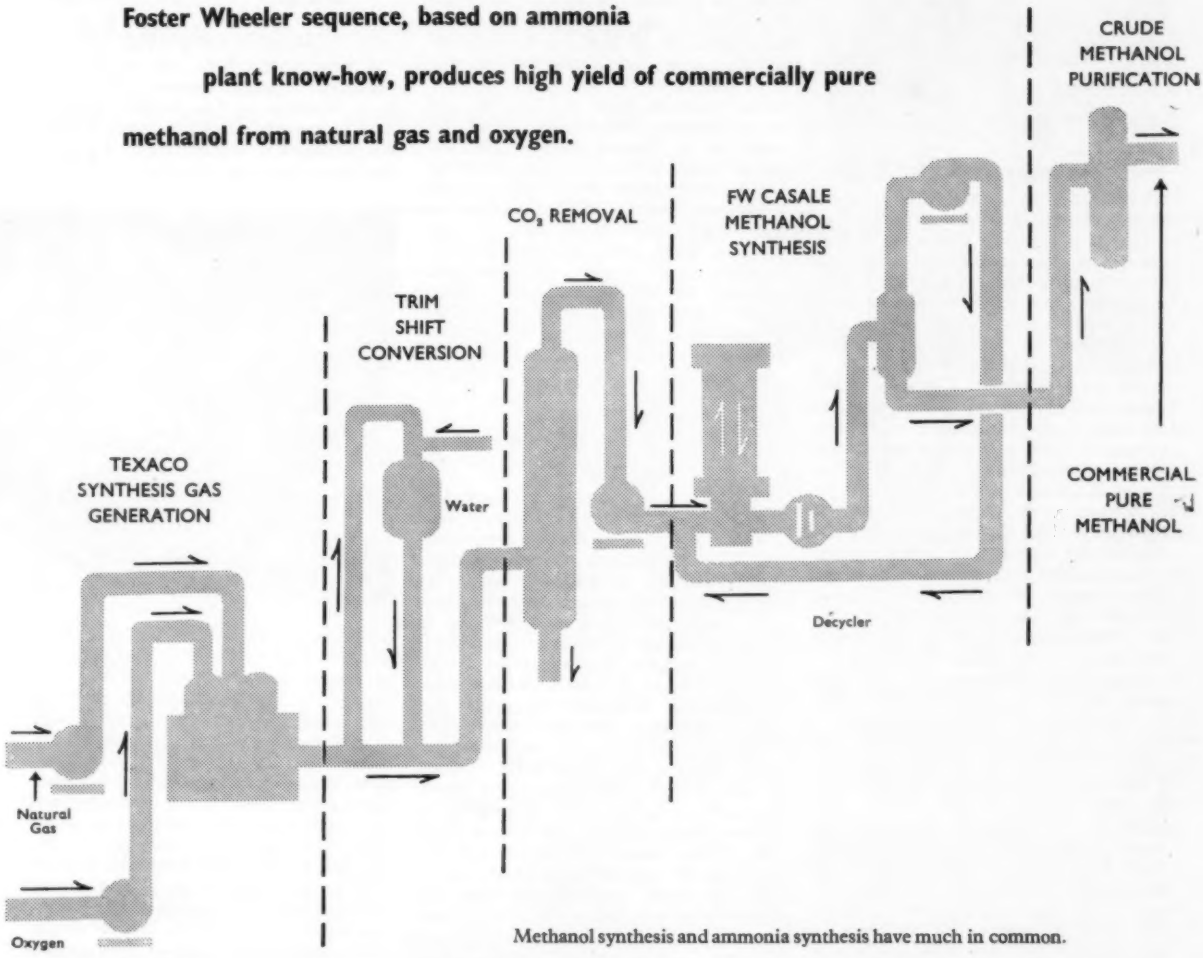
THIS REPORT gives detailed statistics on the European non-ferrous metals market, and depicts market developments in the O.E.E.C. area since 1954.

The statistics on production, consumption and foreign trade of the traditional metals (aluminium, copper, lead, zinc, tin, nickel, together with copper, lead and zinc ores) are brought up to date and preceded by a brief survey of the trend in supply and demand.

For the first time, the report includes comparable statistics on the principal metals used at the first processing stage in the form of primary or secondary metal, scrap and residues. It is illustrated with graphs on production, consumption, metal uses and price trends.

methanol

Foster Wheeler sequence, based on ammonia plant know-how, produces high yield of commercially pure methanol from natural gas and oxygen.



Methanol synthesis and ammonia synthesis have much in common. Hence Foster Wheeler's accumulated knowledge derived from the construction and successful operation of six large ammonia plants, is of great value in the planning and construction of modern methanol units.

The FW sequence for production of commercially pure methanol is shown above.

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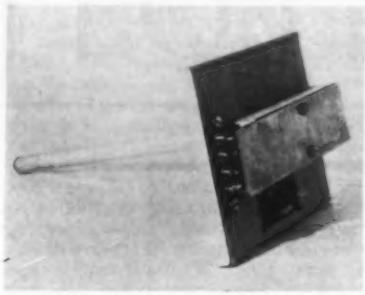
PLANT EQUIPMENT NEWS



Resistance Thermometer for 1200°C

A resistance thermometer which gives stable performance at temperatures of up to 1200°C is the latest product of C.N.S. Instruments. Among the novel features it embodies is the absence of weld between the platinum wire element and the leads—the platinum wire which forms the element being continued down the protecting sheath as leads. The element is wound on a former which locates the platinum wire within fine limits and therefore keeps it free from strain irrespective of expansion and contraction due to temperature changes. The sheath is of recrystallised alumina which is guaranteed by its makers to be impermeable even to hydrogen at 1700°C. The sheath and the multiple tube within it are attached to the mounting board by a novel method which allows a degree of flexibility at the point of attachment, the danger spot for fracture. The mounting board is of composition and may be drilled or tapped for locating the thermometer. The leads are protected by a stainless-steel plate attached to the mounting board. A stability enabling a control accuracy of ±1°C at a temperature as high as 1200°C is claimed for the instrument, which, in the measurement of drift over a long period at that temperature, permits of an accuracy equivalent to that of platinum/rhodium platinum thermocouples. The instrument may be used with the company's proportional temperature controller—a type of instrument which, when subjected to a month's continuous test at the National Physical Laboratory, controlled temperature in the region of 600°C to ±0.02°C throughout the period. Such an instrument also completed 32,000 hours of continuous operation (over 3½ years) at the Laboratory when used in creep testing equipment without any maintenance service or valve replacement. It embodies the company's 19-ohm precision potentiometer. **C.N.S. Instruments Ltd., 61 Holmes Road, London, N.W.5.**

BCE 2921 for further information

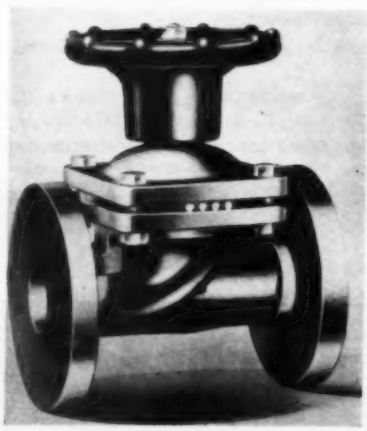
New Orifice

George Kent announce the introduction of the Dall orifice, designed and developed by the research team which produced the Dall tube. The orifice is intermediate both in pressure loss and in cost between the square-edged orifice plate and the Dall tube, and is therefore particularly suitable, the makers point out, for use where pressure recovery is of importance but space or first cost precludes the use of a Dall tube. On a medium-velocity installation working with a 100-in. w.g. instrument, the pressure loss with a Dall orifice was found to be only 19 in. w.g., compared with 60 in. w.g. for an ordinary orifice plate or a flow nozzle and 5 in. w.g. for a Dall tube. The orifice is a self-contained truncated form of Dall tube and has a thickness, where it is clamped between the pipe flanges, of only 1¼ in. The overall length is 0.3 of the pipe diameter, and the downstream cone simply projects a short way into the downstream pipe. At present the fittings are available for 6-in. to 24-in. pipes, and, although they are normally cast in gun-metal, high-grade cast-iron can be used for some applications on 18-in. and larger sizes. They are suitable for water other than sewage, compressed air, low-pressure air, relatively clean and non-corrosive gases, and low-pressure steam such as exhaust steam. **George Kent Ltd., Luton.**

BCE 2922 for further information

New Stop-valve

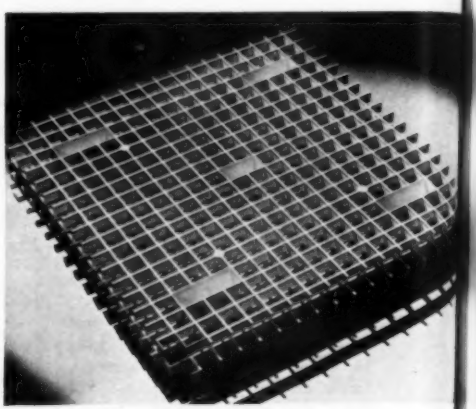
Meynell have introduced a new diaphragm Rayon-patent stop-valve which is designed to be suitable for controlling the flow of almost any liquid or gas up to the temperature of 100°C. Developed in Holland, it is being manufactured by Meynells under British patent 698,849 and is being distributed by them in the United Kingdom and the Commonwealth except Canada. The clack and clack seat have been designed to eliminate pressure on the part of the clack that separates the fluid from the working mechanism. A special safety factor is that, in the unlikely event of the clack leaking or failing, the liquid does not escape as it is retained by a closure above the clack. The valve is available either screwed or flanged and the body can be supplied in cast iron, malleable iron, bronze, aluminium or lined with hard rubber or plastic. The method employed in lining the valve body (for which a patent has been applied) ensures that the valve is also suitable for use in vacuum. The manufacturers claim that the pressure drop through the valve has been reduced to almost nothing. **Meynell & Sons Ltd., Montrose Street, Wolverhampton.**



BCE 2923 for further information

Plastic Tower-packing

A new plastic Poly-grid packing for Counterflo cooling towers designed by Fluor Products of Los Angeles, U.S.A., is being made available by Head Wrightson Processes in Great Britain. The product is described as a combination of film and splash packings, of higher cooling capacity than timber-deck packings, and as uniting the advantages of the lower head of the film cooler with the ability of the splash packing to operate under rugged conditions. In its construction small members of resistant plastic are used. The new packing will have two main applications: (1) for use in newly-designed cooling towers, in the first place where there are special circumstances, for example, where only a small area is available or for pharmaceutical and similar purposes; and (2) for restacking existing cooling towers at plants where greater cooling capacity is required. The packing is covered by patents in the United Kingdom and Europe, and whereas at present Head Wrightson hold adequate stocks in Britain they are investigating the commercial economics of production to tool up for manufacture here. In America Poly-grid packing is made of single-shot four-point mouldings of polystyrene or high-density ethylene 8 or 9 sq. ft in area. Head Wrightson believe that for all industrial and air-conditioning applications the product can take the place of wooden bars or slats. **Head Wrightson Processes Ltd., 24 Baltic Street, London, E.C.1.**



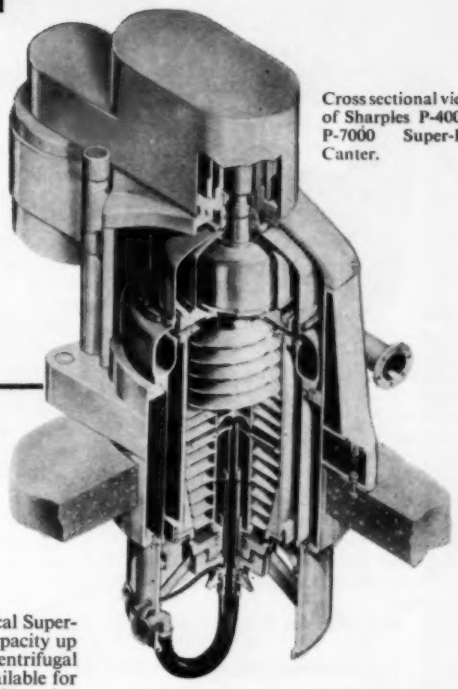
BCE 2924 for further information

Capacitator Hygrometer

A new hygrometer designed to have immediate response, to be stable, easily

8 new Sharples centrifuges

Make the Sharples range still more comprehensive



Cross sectional view of Sharples P-4000 P-7000 Super-D-Canter.

For years Sharples have offered the widest range of centrifuges. Now come no less than 8 new models. This means a still more impressive range which extends still further the scope of service that we can offer on all separational problems.

1 **MODEL P-600** A new cylindrical bowl pilot scale horizontal type Super-D-Canter with a 6" x 14" bowl—a larger version of the already popular P-400 Model.

2 **MODEL P-3000** A cylindrical long bowl horizontal Super-D-Canter extending the range of the P-1000 and P-2000 series. This unit has a clarifying capacity of up to four times that of the P-2000.

3 **MODEL P-4000** A completely new vertical type Super-D-Canter of large liquid throughput capacity, having a centrifugal force of 3100 x g. Designs available for operation at pressures up to 150 p.s.i.g.

4 **MODEL P-7000** A larger vertical Super-D-Canter of solids handling capacity up to 10 tons per hour, with a centrifugal force of 1650 x g. Designs available for operation at pressures up to 150 p.s.i.g.

5 **MODEL C-41** A new high capacity perforate basket centrifuge of the Super-D-Hydrator range. Solids production capacity from 2-4 times that of the already well known model C-27 Super-D-Hydrator.

6 **MODEL DH-5** A new high capacity nozzle centrifuge having a liquid throughput of approximately twice that of the familiar DH-3 Nozljector. Designs available for operation at pressures up to 150 p.s.i.g.

7 **MODEL DH-6** The largest nozzle machine at present in our range, with a capacity of approximately 4 times that of the DH-3 Nozljector. Designs available for operating at pressures up to 150 p.s.i.g. The largest capacity nozzle centrifuge in the world !

8 **MODEL K-8** A pilot-scale Super Classifier for operation at feed rates of up to 250 lbs. an hour of dry powder. Suitable for test plant and for small scale production classification operations. Cut range identical with Super Classifier models K-16 and K-27.

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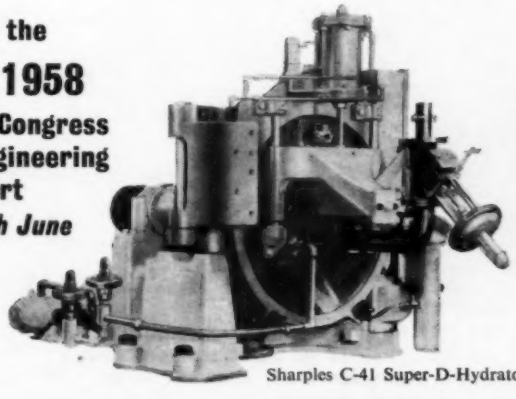
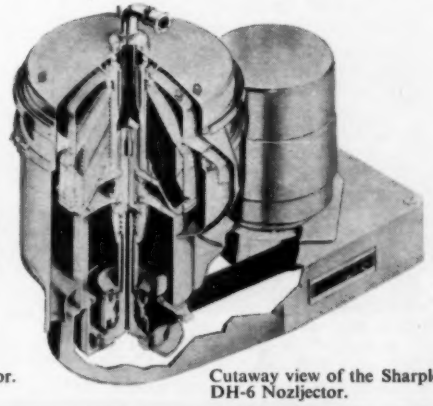


Sharples C-41 Super-D-Hydrator.



Cutaway view of the Sharples DH-6 Nozljector.

Please let us have details of your separation or classification problem —we shall be pleased to submit our UNBIASED recommendations.

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PLANT EQUIPMENT NEWS

checked and standardised, and to be remotely read, has been made available by Shaw. Its small detecting element consists of a capacitor with a hygroscopic dielectric a few microns thick and a 24-carat gold electrode. The instruments have already been used as standards for checking industrial relative-humidity controllers. They may also be used for quick estimation of moisture in hygroscopic materials. **Shaw Ltd., 31 Market Street, Bradford.**

BCE 2925 for further information

Graphite Bursting Discs

Powell Duffryn Carbon Products have introduced a range of bursting disc assemblies in carbon and graphite. The standard range is available in sizes 2-in., 3-in., 4-in. and 6-in. bore, in bursting pressures between 5 and 75 psig, bursting accuracy being guaranteed within ±5% of the rated burst-pressure. For discs rated 20 psig or below, vacuum supports of either bar or dial type are available if there is a possibility of vacuum conditions existing within the vessel. Working pressures may be up to 75% of the nominal burst rating. Temperatures of up to 160°C can be tolerated without deterioration, it is pointed out. Standard factory control procedure involves the application of 10,000 pressure reversals at 75% of burst pressure, followed by full burst pressure which disintegrates the disc within the guaranteed accuracy limits. **Powell Duffryn Ltd., 8 Great Tower Street, London, E.C.3.**

BCE 2926 for further information

Aluminium Tank Suspension

For the transport of liquids, Thompson Bros. have developed a new aluminium alloy tank and three-point suspension system for liquids transport. Basically, the system consists of four pressed box-section members running the full length of the tank and spaced by the tank bulkheads or baffles, which in turn are bridged by vertical flanged members joining the upper and lower box members. Within this structure is carried the tank shell, subjected only to stresses arising from the carriage of its liquid load. The forward end of the tank is supported by a transverse beam secured to the chassis side members through pre-loaded rubber bushes. At the rear, two bolsters incorporating laterally disposed, pre-loaded bushes support the tank. **Thompson Bros. (Bilston) Ltd., Bradley Engineering Works, Bilston, Staffs.**

BCE 2927 for further information

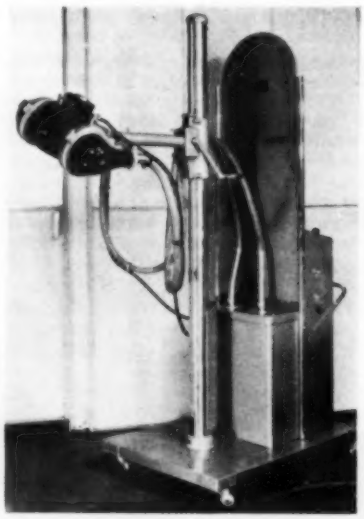
Electrical Test-meter

The recently-introduced Multiminor (model 1) test meter for maintenance engineers is a well-designed, easily-used pocket-rectifier-moving-coil instrument which provides 19 ranges selected by one switch; a single scale for current and voltage and another for resistance measurements. The instrument caters for a voltage range (A.C. and D.C.) of 0-1000 V; a d.c. current range of 1μA to 1A; and it will measure resistance from 0-2 MΩ. Model 2 is for use under adverse climatic conditions. **Avo Ltd., Avocet House, 92 Vauxhall Bridge Road, London, S.W.1.**

BCE 2928 for further information

Industrial X-ray Equipment

Marconi Instruments have added to their range of X-ray equipment a 110-kVp apparatus, type TF 1597, designed for 200-250 volts a.c. operation. It consists basically of three portable units—h.t. generator, control unit and tubehead—

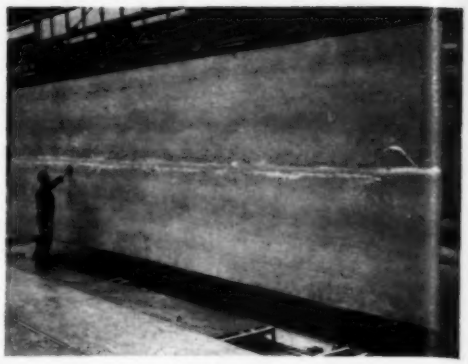


and the company's engineers are prepared to advise on a suitable arrangement of these to meet particular inspection problems. **Marconi Instruments Ltd., St. Albans, Herts.**

BCE 2929 for further information

Wide Aluminium Plate

Aluminium plate for general engineering purposes can now be obtained, for the first time in this country, in widths of up to 11 ft. This new product, developed by Northern Aluminium to overcome limitations of rolling equipment, is produced by butt-welding two plates together, and



the strength of the weld, the makers point out, is higher than can be ensured by welding during subsequent fabrication. Typical properties across the weld in plate to B.S. 1476 : NP5/6, for example, are a 0.1% proof stress of 8 tons/sq. in. (the same as the minimum demanded of unwelded material by this specification), a U.T.S. of 16.3 tons/sq. in. (compared with 17 tons/sq. in. specified) and an elongation of 11% (compared with 12%). **Northern Aluminium Co. Ltd., Banbury, Oxon.**

BCE 2930 for further information

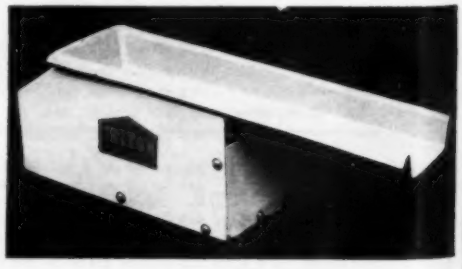
Controller Failure Signal

The new Foster automatic controller failure signal and safety unit provides a mechanism that automatically and periodically checks the functioning of potentiometric self-balancing controllers by sending through the signal generating, measuring and balancing system a periodic test signal. If the signal fails to get through it causes an alarm to be given and, if required, automatic shut-down or safeguarding action to be taken. The frequency and strength of the test signal can be set to suit the "run-away" time of the controlled process and the balancing speed of the controller. The device is fitted with an alarm which functions should its own prime mover fail. **Foster Instrument Co. Ltd., Letchworth, Herts.**

BCE 2931 for further information

Vibrating Feeder

Triton have made available a new small-output vibrating feeder, type TM1, designed to be of particular use in the chemical, food, pharmaceutical and animal feed industries, and in test grinding, etc., where low feed rates are required. It operates on an electromagnetic principle, and, as the ventilated control unit is wired for mains working, the instrument functions without a transformer. The rate of

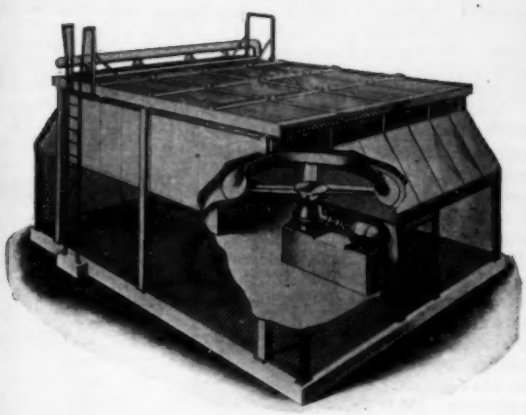


FIN-FAN

AIR COOLED HEAT EXCHANGERS

provide guaranteed temperature control and economic operation

The simple and robust construction of the fin-fan, which is made up of a minimum number of standardised parts, combines appearance with utility. These forced draught coolers are powered by electric motors, gas or diesel engines, steam turbines, etc., using adjustable pitch propeller type fans, and can be employed in a great variety of waste heat dissipation duties at pressures from vacuum to 5,000 p.s.i. or temperatures to 1,500° F.



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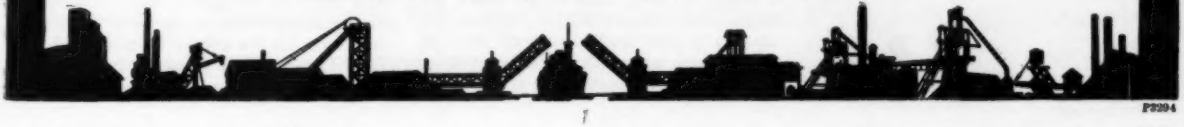


P2294

PLANT EQUIPMENT NEWS

feed is adjusted by the use of a graduated dial. At its lowest rate the equipment will feed as little as, for example, 1 lb. an hour of salt, and, at its maximum rate, about 150 lb. an hour of dry sand, having a bulk density of 100 lb./cu. ft. The trough dimensions are 9¼ in. × 1¼ in. × ⅛ in., and the current consumption 50 milliamps. **The Triton Engineering Co. (Sales) Ltd., 216 Sydenham Road, Croydon.**

BCE 2932 for further information

Smoke Control Equipment

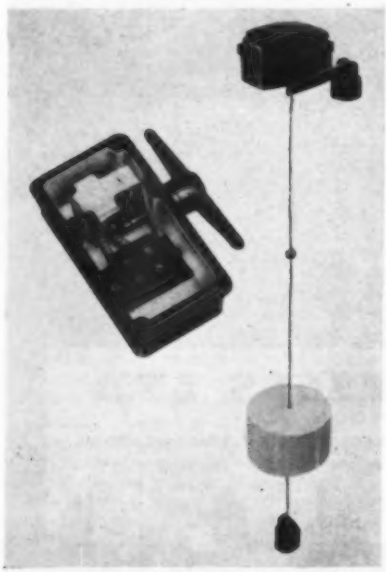
Photoelectronics have introduced two new smoke-control instruments embodying printed circuits. Smoke alarm type PCSA is suitable for chimneys up to 10 ft in diameter and complies with B.S.S. No. 2740 : 1956. Their smoke density indicator, type PCSI, complies with B.S.S. No. 2788 : 1957 and is suitable for chimneys up to 40 ft in diameter. The company has also made available a new light-actuated switch which operates from a phototransistor and requires no valve amplifier. **Photoelectronics (M.O.M.) Ltd., 63a Kingston Road, London, S.W.19.**

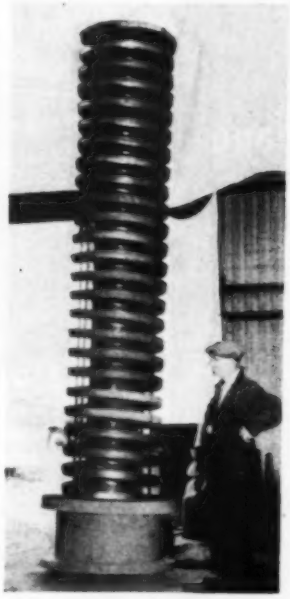
BCE 2933 for further information

Mercury Floatswitch

Girdlestone's new MS-5 mercury tube Floatswitch is designed to be specially suitable for use with corrosive fluids and in difficult working conditions. It is housed in a heavy cast-iron weatherproof case, and the single-pole mercury tube is carried in a phosphor-bronze cradle actuated by a positive spring-controlled tilting mechanism. Expanded polystyrene floats suitable for liquids up to a temperature of 150°F are fitted as standard equipment, but float gear in copper for use at temperatures exceeding 150°F and in stainless steel or polythene for certain corrosive fluids can be supplied. **Girdlestone Pumps Ltd., 23 Davies Street, London, W.1.**

BCE 2934 for further information





Going up: The tallest spiral elevator so far supplied by The Magnetic Equipment Co. Ltd., Lake Works, Portchester, Hants., under their plan to build bigger equipment of this kind—a 12-ft model, having an output of about 2 tons an hour. A 20-ft tall model with a delivery of 5 tons an hour is under construction.

Precision Vacuum Oven

The Gardiner precision vacuum oven recently made generally available by Griffin & George was primarily designed for drying labile products such as sugar syrups and molasses containing fructose and to provide a standard reference method for the determination of water in sugar products. The oven was developed in the Tate & Lyle Research Laboratories, and it can be used, the makers point out, whenever exact and reproducible results of experiments on drying losses from other materials, particularly of a labile nature, are required. **Griffin & George Ltd., Ealing Road, Alperton, Middlesex.**

BCE 2935 for further information

Other Items of Interest

The Paints Division of I.C.I. has introduced the Serseal layer process for eliminating fumes and steam from aqueous metal treatment baths and for reducing heating costs in these processes. It seals the surface of the processing liquid with a layer of inert material to check the fumes and steam and to reduce the amount of heat needed to keep the bath at a working temperature. Fuel economies of up to 75% under production conditions are claimed for the process. **Imperial Chemical Industries Ltd., Millbank, London, S.W.1.**

BCE 2936 for further information

Baldwin Instruments have introduced a mechanism which permits a solenoid-operated fluid-power control valve to be operated manually when the electrical supply is not available. It consists essentially of a shaft which enters through the end cover of the valve to make contact with the pilot piston head which is connected to the spool. **Baldwin Instruments Co. Ltd., Brooklands Works, Dartford, Kent.**

BCE 2937 for further information

Maplebond, recently developed for the welding of pipes in cathodic protection, is a 1 in. × ⅛ in. copper bar with tails for thermit welding on each side of the joint. **Metal & Pipeline Endurance Ltd., Artillery Mansions, Victoria Street, London, S.W.1.**

BCE 2938 for further information

A self-contained vibration indicator, type 1414, has been made available by Dawe Instruments. It is used with a vibration pick-up of the inertia-operated crystal type delivering a voltage proportional to the acceleration of the object with which it is in contact. **Dawe Instruments Ltd., 99 Uxbridge Road, London, W.5.**

BCE 2939 for further information

Two new industrial humidifying units have been introduced by Aerosol-Turbo. Type W.573 for volumes of up to 100,000 cu. ft and type W.561 for volumes of 3000 to 4000 cu. ft. **Aerosol-Turbo Ltd., 14 Cross Belgrave Street, Leeds, 2.**

BCE 2940 for further information

Locks point out that no electrical knowledge is required to use their new universal *p*H meter test set, which may be used for the setting up of automatic titrators, *p*H recorders and controllers. **A. M. Lock & Co. Ltd., 79 Union Street, Oldham.**

BCE 2941 for further information

New Publications

What is believed to be the first-ever published booklet on the use of cationic chemicals for pigments and surface coatings has been forwarded to us by the **Chemical Division of Armour Chemical Co. Ltd., Lindsay Street, London, E.C.1.**

BCE 2942 for further information

Rototherm's latest catalogue (57-H) of thermometers, recorders and controllers is in two sections. The first section deals with Rototherm's bi-metal dial thermometers for use in many and diverse applications, and the second section with their mercury-in-steel thermometers, recorders and controllers, vapour pressure thermometers, vacuum and pressure gauges and recorders. Copies from **The British Rototherm Co. Ltd., Merton Abbey, London, S.W.19.**

BCE 2943 for further information

The 1958 catalogue produced by I.A.C. Ltd. contains a selection of this company's more popular and most commonly used mercury switches. I.A.C. state that they also undertake to manufacture mercury switches for special purposes. **I.A.C. Ltd., Chase Road, London, N.W.10.**

BCE 2944 for further information

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With over 150 Current models of Centrifugal Separators to choose from and backed by over 75 years experience in their application De Laval can offer you the best advice and the widest range of equipment.

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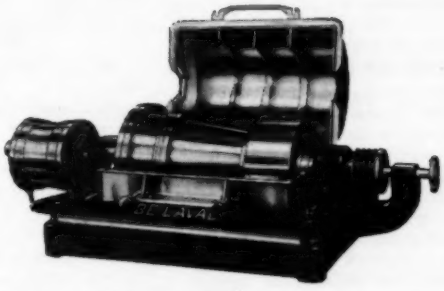

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A Horizontal centrifuge with helical Screw for the continuous Separation of Solids from a Liquid.

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An entirely new high capacity Hermetic Clarifier. Complete freedom from air contact enables gaseous liquids to be processed.

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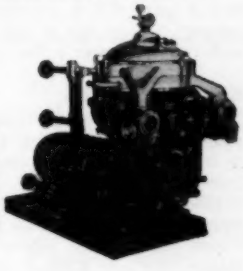
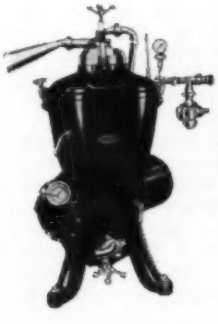
High efficiency disc type Separator—Discharges solids automatically while running at full speed—Cuts out bowl cleaning —reduces labour.





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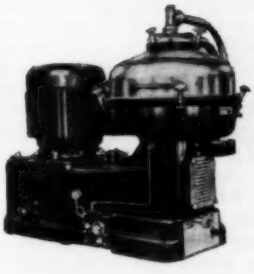
A Hermetic Separator for oil degumming or soapstock separation as used in the De Laval Short Mix Refining Process.

DE LAVAL NOZZLE SEPARATOR QX 212

For continuous discharge of solids in Liquid/Solid separations. High capacities up to 20,000 g.p.h.



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Month's News in Brief

Shell's Computing System

A high-speed electronic computing system has been ordered from Ferranti Ltd. by Shell to solve complex mathematical problems. It will be installed in Shell's London office and will be used for special calculations covering commercial aspects of all activities from exploration to marketing. The present order has been largely influenced by Shell's successful experimental work over the last three years on the Ferranti electronic computer in their Amsterdam laboratory. This has demonstrated that computers allied with new mathematical techniques can make a real contribution towards the analysis of intricate business problems, thus assisting management in deciding on the best course of action in complex situations. The new computing system is expected to be in full operation early in 1959.

B.P.'s Distillation Unit on Stream

The new distillation unit which increases the annual capacity of B.P.'s Kent refinery on the Isle of Grain from 4,600,000 tons to over 7,000,000 tons a year was commissioned during February. The distillation unit is the first major plant to come on stream in the refinery's £30,000,000 expansion project. When the project is completed later this year, the refinery will be capable of producing about 130,000 tons a year of aviation gasolene, in addition a greatly increased quantity of other oil products. In all, 21 new processing units will be commissioned at the refinery between now and August. When completed, the Kent refinery will be one of the most modern and comprehensive refineries in Europe.

New Paper Process

A new process for making high-quality printing paper by which yields of pulp from the esparto grass can be increased from 40 to 58%, with no apparent deterioration of the quality of the product, has been elaborated by the British Paper and Board Industry Research Association of Kenley, Surrey. Other advantages of the process include economies in the quantity of caustic soda used, flexibility and adaptability to automatic control. It is also suitable for use with straw. In the course of the researches, much new information about pulping processes was gathered. Application is being made for a patent for the process.

Weir's Atomic Contract

Twenty Weir feed pumps have been ordered for the Hunterston nuclear power station now being constructed for the South of Scotland Electricity Board. The station is the first nuclear power station to be constructed for the Board and represents one of the largest additions to the electricity supply grid in Scotland. The order was placed by Simon-Carves Ltd., who are associated with the G.E.C. in the construction of the Hunterston station. The main pumps are to be fitted with Weir relay-operated automatic by-pass valves to protect the pumps in light-load operation.

Procon's German Platformer

A combination UOP platforming-unifining unit, which includes gas concentration facilities for producing LPG, has gone on stream at the refinery of Deutsche Erdol - Aktiengesellschaft, Heide, Germany, as part of an expansion programme which began shortly after the refinery was rebuilt following the Second World War. The platformer (the sixth operating in Germany) was constructed by Procon (Great Britain) Ltd. in co-operation with Edeleanu Gesellschaft m.b.H., Frankfurt/Main, and was designed, engineered and licensed by Universal Oil Products Co., Des Plaines, Illinois.

News Briefs

Simon-Carves Ltd. are to build for Du Pont S.A. de C.V. in Mexico a sulphuric acid plant with a capacity of 60 short tons of acid a day. They have undertaken to ship the whole of the equipment from Britain in less than seven months. The plant will be paid for in American dollars, the contract value for which is approximately $250,000.

To improve the control aspect of the plant for gaseous diffusion of uranium hexafluoride at Capenhurst, the United Kingdom Atomic Energy Authority has awarded to Sunvic Controls Ltd., an A.E.I. company, a contract for a data-handling system which, as envisaged, will be the largest in Europe, both as regards value and number of points scanned.

The National Union of Teachers is to sponsor the first National Education and Careers Exhibition from May 25 to June 4 (National Hall, Olympia) next year. Her Majesty the Queen has consented to be patron.

The Self-Priming Pump & Engineering Co. Ltd., of Trading Estate, Slough, Bucks, will in future be known as SPE Co. Ltd.

The Dunlop Rubber Co. has become a patron of the Society of Instrument Technology.

F. W. Berk & Co. Ltd. have moved to their new head office building—Berk House, Portman Square, London, W.1. Tel. HUNter 6688. Berk's industrial dryer division, the powder metallurgy division and microniser plant department will also transfer from their present separate offices to Berk House.

The Midlands office of Wild-Barfield Electric Furnaces Ltd. is now at 71 Broad Street, Birmingham, 15. Tel.: Midland 7232.

Foxboro-Yoxall Ltd. are now in occupation of their new offices at Redhill, Surrey. Tel.: Redhill 500.

The Chemical Division of Armour & Co. Ltd. are now at 4 Chiswell Street, Finsbury Square, London, E.C.1. Tel.: METropolitan 0031.

People in the News

New appointments announced by the United Kingdom Atomic Energy Authority mark a first stage towards implementing recommendations made by the committee appointed by the Prime Minister under the chairmanship of **Sir Alexander Fleck** to examine the organisation of certain parts of the Authority. The appointments are as follows: **Mr. J. C. C. Stewart,** formerly director of Technical Policy in the Industrial Group at Risley, becomes a deputy managing director of the Industrial Group; **Mr. J. B. W. Cunningham,** formerly deputy director (Civil Reactors), becomes director of Industrial Power in the Industrial Group; **Dr. R. Hurst,** formerly chief chemist in the Research and Development Branch of the Industrial Group at Risley, becomes director of the Dounreay Experimental Reactor Establishment; **Mr. D. S. Mitchell,** formerly director of Administration, becomes director of Personnel and Administration in the Industrial Group; and **Mr. D. W. Fry,** chief physicist at Harwell, who has been appointed a deputy director of the Atomic Energy Research Establishment.

Mr. H. A. C. McKay of the chemistry division, Atomic Energy Research Establishment, Harwell, has been appointed director of the Baghdad Pact Nuclear Training Centre from July, 1958, in succession to **Mr. W. J. Whitehouse.** The Baghdad Nuclear Training Centre, established in 1956, is, in its early stages, concentrating on the practical applications of radio-isotopes to the problems of Middle Eastern countries and is organising intensive short courses in the uses and techniques of these materials.

Spirax-Sarco Ltd., of Cheltenham, announce that the boards of their various English companies are now constituted as follows:

Spirax-Sarco Ltd.: **Mr. H. Alwyn Smith,** chairman and joint managing director; **Mr. L. G. Northcroft,** joint managing director; **Mr. E. M. J. Edwards; Mr. W. M. Barber,** technical sales director; **Mr. B. W. Gregory,** production director; **Mr. R. D. Harding,** commercial sales director; and **Mr. S. M. Haines** secretary.

John Such & Sons Ltd.: **Mr. H. Alwyn Smith,** chairman and managing director; **Mr. L. G. Northcroft; Mr. S. A. Such;** and **Mr. S. M. Haines,** secretary.

Heat Transfer Ltd.: **Mr. L. G. Northcroft,** chairman; **Mr. A. H. Giles,** joint managing director; **Mr. D. P. Golch,** joint managing director; and **Mr. H. Alwyn Smith.**

Mr. K. A. M. Barton (sales director) and **Dr. R. A. Gregory** (production director) have been appointed joint managing directors of Midland Silicones Ltd. **Mr. S. Barratt,** the former managing director, continues to serve on the board as a non-executive director. It will be recalled that Mr. Barratt was recently appointed chairman of Albright & Wil-

BCE 2868 for further information

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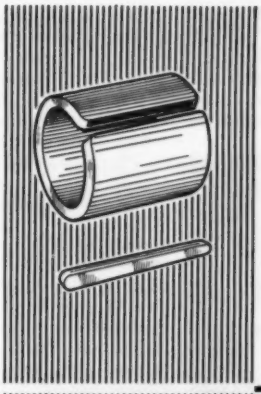
BUSHES



WALTER PATENT SPLIT BUSHES

in

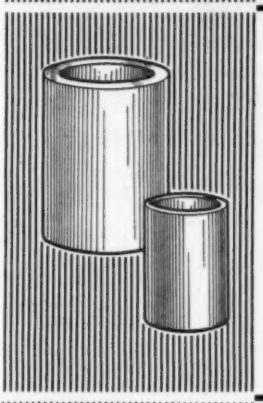
CASE-HARDENED STEEL

NON-CORRODIBLE HARDENED STAINLESS STEEL

NON-CORRODIBLE BRONZES

Manufactured in other materials to customer's specification

Supplied with taper keys in size range ⅜" to 12" internal diameter



PLAIN BUSHES

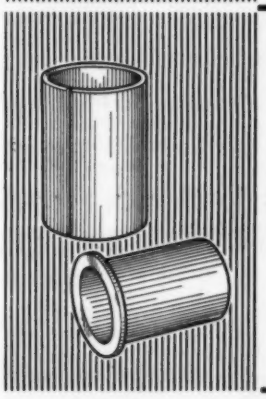
in

HARDENED & GROUND STEELS

HARDENED STEELS (Burnished finish)

NON-CORRODIBLE HARDENED STAINLESS STEELS (Ground or Burnished Finish)

BRONZES - Thin or thick walled



WRAPPED BUSHES

in

STEEL

BRONZES - Thin or thick walled

FLANGED BUSHES

in

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BRONZE

- Manufacture of Bushes in other materials to customer's specification
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son Ltd., parent company of Midland Silicones Ltd.

Mr. L. H. Cooper, chairman of The Mond Nickel Co. Ltd. and vice-chairman of The International Nickel Co. of Canada Ltd., has been elected a director of that company.

Mr. N. J. Travis, managing director of British Visqueen Ltd., a subsidiary of Imperial Chemical Industries Ltd., has resigned from the company. Mr. Travis has had over twenty years' service with I.C.I. and its associated companies. He joined the board of Borax Consolidated

A. R. Thom

George C. Fairbanks

Ltd. on February 1, 1958. Mr. Travis is succeeded at British Visqueen Ltd. by **Mr. A. R. Thom,** who joined I.C.I. in 1946, and was associated with the development of polythene film in its early days.

Elliott Bros. (London) Ltd. announce that **Mr. George C. Fairbanks,** a deputy general manager of the company, has been appointed a director. In the reorganisation immediately following the war, Mr. Fairbanks was appointed production manager at Lewisham, and subsequently, as the company continued to expand, he assumed various senior executive positions including his appointment, two years ago, as a director of the Fisher Governor Co. Ltd. and Bristol's Instrument Co. Ltd., both Elliott subsidiaries.

L. L. Whiteneck, vice-president and director of materials research for Plicoflex Incorp., Los Angeles, California, has been elected president of the National Association of Corrosion Engineers (N.A.C.E.). He will take office, with others, on the last day of the March 17 to 21 Annual Conference and Exhibition in San Francisco. The 1957 N.A.C.E. Willis Rodney Whitney Award will be given to **Dr. T. P. Hoar,** lecturer in metallurgy, Cambridge University, England. The Frank Newman Speller Award will go to Robert J. Kuhn, for more than 30 years corrosion engineer for New Orleans Public Service Incorp. New Orleans, Louisiana. The awards will be presented during the annual banquet of the N.A.C.E. on March 19 at San Francisco.

Extrudex Ltd., who are in the process of doubling production capacity to meet the increasing demand for plastic tubes, fans and fume extraction equipment in industry, announce the appointment of **Mr. J. E. Davies** as sales manager and also that of **Mr. M. J. Howard,** who has been appointed works manager at their Bracknell factory.

Mr. J. Strong, a director of the British Oxygen Co. Ltd., has relinquished his appointment as chairman of Quasi-Arc Ltd. on being appointed chief executive director of British Oxygen Gases Ltd.

British Oxygen Chemicals Ltd. have appointed two new directors. They are **Mr. Leslie G. D. Sheldrake,** as works director, and **Mr. J. M. Williams,** who becomes sales director.

Mr. R. G. Lewis, formerly general manager of Birwelco Ltd. and Brown Fintube (Great Britain) Ltd., and a director of Petrochem G.m.b.H. and of Servotomic Ltd., has now been appointed a director and general manager of the two former companies.

Mr. J. Maurice Laing, managing director of John Laing & Son, has succeeded Sir Richard Costain, chairman of Richard Costain, as chairman of the export group for the constructional industries. **Mr. E. C. Beck,** director of John Mowlem & Co., has been appointed senior vice-chairman; **Mr. P. W. E. Holloway,** director of Holloway Bros. (London), junior vice-chairman; and **Mr. H. J. Patterson,** Dorman Long (Bridge and Engineering), honorary treasurer. **Sir Richard Costain** and **Mr. Frank Taylor,** of Taylor Woodrow Construction, continue in office as the two immediate past-chairmen.

Meetings of the Month

Institution of Civil Engineers

March 18. At the Institute, St. Georges Street, London, S.W.1. The James Forrest Lecture by Sir John Cockcroft. **5.30 p.m.**

Institution of Chemical Engineers

March 18. *North-western Branch:* At Reynolds Hall, College of Science and Technology, Manchester. "Heat Transfer in Relation to Nuclear Engineering." **7 p.m.**

April 16. *North-western Branch:* Joint meeting with the Institute of Petroleum. "Heat Exchange Equipment." Details to be announced.

April 16. *Midlands Branch:* At Midland Institute, Paradise Street, Birmingham. "Synthetic Rubber Plants." **6.30 p.m.**

Society of Instrument Technology

March 25. Manson House, Portland Place, London, W.1. "Evaluation of Instruments for the Process Industries." **7 p.m.**

April 16. *Control Section:* At Manson House, Portland Place, London, W.1. "Electronically-operated Power Plant Instrumentation and Control." **7 p.m.**

April 16. *Tees-side Section:* At Cleveland Scientific Technical Institute, Corporation Road, Middlesbrough. "Some Aspects of Flow Measurement." **7.30 p.m.**

Institution of Mechanical Engineers

April 1. At 1 Birdcage Walk, London, S.W.1. Leonardo de Vinci Lectures. "Rockets and Guided Flight." **10 a.m. till 2.45 p.m.**

April 9. *Steam Group:* At 1 Birdcage Walk, London, S.W.1. Discussion: "Problems Arising from Steam Conditions in Nuclear Power Stations".

April 17. *Applied Mechanics Group:* At 1 Birdcage Walk, London, S.W.1. Discussion: "Training in Engineering Design". **6 p.m.**

Society of Chemical Industry

April 8. *Chemical Engineering Group:* At 14 Belgrave Square, London, S.W.1. "Evaporation of Temperature-sensitive Materials." **5.30 p.m.**

Physical Society

April 10. *Low Temperature Group:* At Oxford. Conference on "The Detection of Damage in Metals by Low-temperature Electrical and Thermal Resistivity Methods". Details to be announced.

Institute of Petroleum

April 2. At 26 Portland Place, London, W.1. "Electrostatics and Explosion Hazards in the Petroleum Industry." **5.30 p.m.**

This Month's Events

Home

Details of the Chemical and Petroleum Engineering Exhibition, sponsored by the British Chemical Plant Manufacturers' Association and the Council of British Manufacturers of Petroleum Equipment, may be obtained from the organisers, F. W. Bridges & Sons Ltd., Grand Buildings, Trafalgar Square, London, W.C.2, and not from the Institution of Chemical Engineers as given in our Exhibitions Diary for 1958, published in the March issue, p. 151.

March 17. *Association of British Chemical Manufacturers' Packaging Conference:* At Buxton, Derbyshire, until March 20.

March 24. *Physical Society's Exhibition:* At the Royal Horticultural Society's Hall, London, until March 27.

March 24. *Fourth International Instrument Show:* At Caxton Hall, London, until March 29.

March 25. *Institute of Mechanical Engineers Conference, Technology of Engineering Manufacture:* At the Institute of Mechanical Engineers, London, until March 27.

March 25. *Electrical Engineers' Exhibition:* At Earl's Court, London, until March 29.

April 10. *F.B.I. Conference on Nuclear Energy:* At Eastbourne until April 12.

April 14. *Factory Equipment Exhibition:* At Earl's Court, London, until April 19.

April 16. *Instruments, Electronics and Automation Exhibition:* At Olympia, London, until April 25.

April 17. *Royal Institute of Chemistry —Annual Conference:* At Edinburgh until April 19.

Overseas

March 17. *National Association of Corrosion Engineers — Annual Conference:* At San Francisco, California, until March 21.

April 12. *Japan's International Trade Fair:* At Osaka until April 27.

April 14. *Third Design Engineering Show:* At Chicago, until April 17.

April 17. *Brussels World Exhibition:* At Brussels, Belgium, until October 19.